# Design and Technology Education: An International Journal

28.2

# Design and Technology: An International Journal

**Design and Technology Education: An International Journal**
(formerly The Journal of Design and Technology Education) is published three times a year



**Contributions**
All contributions and materials for review should be made through the Journal website at:
**https://openjounals.ljmu.ac.uk/DATE**

**D&T Association membership**
To join the D&T association, or request further details on membership please contact:
Jacqui Eborall, Membership Secretary
Tel: 01789 470007
email: membership@data.org.uk



**Volume 28**
**Number 2**
*ISSN 2040-8633 (online)*
*November 2023*

## Issue 28.2

## Table of contents

# Design and Technology Education – a lone discipline or a discipline that sees the value of collaboration?

**Kay Stables, Goldsmiths, University of London, UK**
**Lyndon Buck, Aston University, UK**

This issue of the Journal is rather special, in that, along with articles submitted in the normal way, it also includes a Special Issue of articles that have been prepared as part the BRACE project - a project that has formed a community of researchers, some of whom are practicing teachers and some of whom are university academics, all working together. So, following this editorial is a second Guest Editorial that provides background to the project and introduces the BRACE project articles.  These are made up of a book review and the first four research articles in this issue.

In information about our journal displayed on the journal's website we state that the journal provides a "broad and inclusive platform for all aspects of Design and Technology Education, Design Education and Technology Education in primary, secondary and higher education sectors, initial teacher education (ITE) and continuing professional development (CPD)". Quite frequently articles are submitted that don't match these requirements, most commonly from authors submitting articles about educational technology with no connection to design and technology education. But sometimes articles are submitted that are on the cusp – a word that the dictionary tells us is "a point of transition" or "a pointed end where two curves meet". Making decisions about the suitability of such articles can be quite awkward – where do we draw the line, are we opening up floodgates, are we staying true to our mission? But while we champion the website statement, we also recognise that reality goes beyond disciplinary boundaries and that positive developments occur at points of transition and when two curves meet. Concepts such as "interdisciplinarity", "transdisciplinarity" and "postdisciplinarity" are increasingly breaking down barriers as people from different disciplines work together to address tricky challenges that can't be sorted by a lone discipline. So, back to the awkward decisions. Occasionally articles on the cusp arrive that are so interesting, that make a valuable contribution to design and technology education but that also are beyond the disciplinary boundary. In this issue we present several such articles, each of which we believe is important, interesting, and adds something special to this issue of the journal. We hope readers agree and would be pleased to receive any comments or future contributions on this topic.

Below are brief overviews of this issue's articles. We hope you find the overviews useful and enjoy reading the full articles.

We start with *The Place of Design Education in Achieving 4IR Sustainability through the 4Cs Skill-sets* by Peter Oluwagbenga Odewole, Tolulope Oladimeji Sobowale, and Festus

Osarumwense Uzzi, from Olabisi Onabanjo University, Nigeria who provide a highly detailed and valuable analysis of the challenges of addressing the United Nations' agenda for achieving the 17 Sustainable Development Goals, interlaced with the challenges of the Fourth Industrial Revolution. Within this they highlight the crucial contribution of what are commonly referred to as the 4C's - Communication, Creativity, Critical thinking and Collaboration – and the important role that design and design education have to play in conjunction with the 4C's in dealing with these challenges. The article provides an excellent scholarly review of research that highlights the importance and potential of design and design education as they address the future challenges faced. Each of these aspects focused is handled in a thorough and methodical way. Their scope is both wide and deep as they draw the main threads together and provides and extensive, rich collection of research and researchers, while making a strong case for design education. A valuable resource.

In *Preschool teachers' experiences of technological concepts in relation to everyday situations in the preschool*, Maria Svensson, Jonna Larsson, Ann-Marie von Otter, and Pia Williams from the University of Gothenburg, Sweden and Helena Sagar from the Municipality of Kungsbacka, Sweden conducted research with pre-school teachers to understand how they experience technological concepts in everyday situations. Starting with an outline of the importance of the teachers understanding technological concepts and the challenges they face in gaining this understanding, the authors report on research that was initiated by the preschool teachers approaching the researchers. Semi-structured interviews with twelve teachers involved a discussion prompted by photos that teachers considered to include technology in everyday situations. Analysis of the interviews allowed the researchers to build units from interview excerpts to compare and contrast. Four distinct categories emerged – exploring techniques, exploring techniques using artefacts, exploring artefacts as technology and developing constructions using artefacts. The researchers found that it was the last category where technological concepts were most developed. The categories and the examples given by the teachers provide valuable insight into pre-school teachers' understandings of technological concepts and, through this, approaches that can support teachers to understand how these concepts can be introduced through everyday activities.

In *Exploring Inclusive Design and Digital Humanities: Enabling Bilingual Digital Narratives for Deaf Children*, Cristina Portugal, Monica Moura, and Jose Carlos Magro Junior from São Paulo State University, Brazil and Marcio Guimarães, from Federal University of Maranhão, Brazil take an interdisciplinary approach in which design is seen as a cultural practice and is a central contributor to research that explores the potential of digital technologies in supporting the development of bilingual visual narratives where the bilingualism is between the language of Portuguese and Brazilian Sign Language LIBRAS. Taking inclusive design as an overarching approach, their research centres on creating bilingual digital stories in a digital book for deaf and hearing children. Research involved ten children aged between 5 and 7, five being deaf and five hearing, who interacted with digital books created by the authors. Close observation of the children focused on aspects such as engagement and interest, ease of use, comprehension of content and interaction with bilingual resources. It uncovered insights into the value of the bilingual approach in relation to areas such as language development, contextualised learning and the use of visual stimuli. The research has led to important guidelines for integrating Portuguese and LIBRAS as well as guidelines for creating bilingual stories through visual narratives. This article is uplifting through the insights that can be gained not just because of the specifics of the impact of the bilingual digital stories but also through the recognition of the value of design within an interdisciplinary framework and, in this case, its impact on young children's learning. A glimpse of the digital stories is available through a hyperlink within the article.

In *Exploring Girls' Narratives in Competition-Based Educational Robotics*, Thomas Kennedy from Memorial University of Newfoundland, Canada focuses on the perceived sense of comfort of girls engaged in an educational robotics competition. The research involved five girls, aged 15-16, in the Marine Education Advanced Education (MATE) underwater remotely operated vehicle (ROV) program in Eastern Canada. The girls engaged in a competition at two levels: a school based intragroup competition and at a provincial intergroup competition. The author conducted a qualitative case study with three phases. First was a questionnaire designed to gather insights into the participants' preliminary perspectives and begin to build a profile. The second phase involved semi-structured interviews based on a 1-to-1 basis to allow the girls to speak independently and also included observation of the participants. The final phase provided an opportunity for the participants to review the data collected on them. The findings provides a fascinating insight into the girls' views on engaging in robotics and in the competitions. The research highlighted aspects such as the extent to which the girls valued their relationship with their peers and confirmed that this relationship fostered comfort, belonging and a connected social identity. They felt safe, could take risks, make mistakes. But views on continuing without the others in their team was rather different, raising issues such as levels of competence and knowledgeability in comparison to other teams and concerns about their performance and acceptance. Interestingly the participants commented on stereotypical 'geekishness' amongst other (typically male) competitors, but felt themselves to be different, although were concerned about being stereotyped. The article provides detailed insight into the lived experience of these girls that is both informative and fascinating.

In *A framework for analyzing technological knowledge in school design projects including models*, Björn Citrohn, from Linköping University, Sweden, analyses three common school design projects to explore the technological knowledge associated with the physical models that can be drawn from these projects. Based on a framework from a previous study, he documented (via video) and analysed three complete design projects undertaken by learners in Sweden's Grades 7, 8 and 9. The projects were ones commonly used in technology education in and beyond Sweden – designing a bridge, designing a mini greenhouse and designing a pedometer. His data allowed detailed insight into the learning that took place in each project, based on the previous framework's categories plus new ones that emerged - technical skills, technological scientific knowledge, socio-ethical technical understanding, engineering capabilities and technological research capabilities.

The research would be of considerable interest to teachers in reviewing the learning potential within particular design projects, particularly as the categories in the framework that emerged provide insights that go beyond a narrow skills focus. This research opens up opportunities to analyse and plan design projects that are rich with learning opportunities.

Heillyn Camacho and Lone Dirckinck-Holmfeld from Aalborg University, Denmark and Geoffrey Tabo from Gulu University, Uganda present a rather different article that takes a Design Based Research approach focusing on *How to support teachers in becoming teachers as designers of student-centred approaches*. They present a range of literature on approaches such as design thinking and design tools that have been used more generally in education but then take a more embedded design perspective, focusing on "What is design? What truly happens during the design process? How can we approach problems with a designer's way of thinking? How can we perceive learners through the lens of design?" Empirical work was conducted using a design based research approach in a Digital Learning Innovation project and a Student-Centred e-Learning Implementation Methodology in two East African universities. University educators from different disciplines engaged in a prototype Learning Designer Workshop. The workshop involved a series of design tools. Drawing from their findings they identify a set of design principles to support teachers becoming designers. The combination of the workshop tools (that can be downloaded from the article) and the design principles that are outcomes from their research, creates an impressive and valuable resource, providing insights into detailed and deeply considered approaches to support teachers that have potential to benefit the professional practices of those whose backgrounds are from outside of design as well as design and technology educators themselves.

In *Educating designers with 3D printers: a postphenomenological perspective on maker design pedagogy*, Nenad Pavel from Oslo Metropolitan University, Norway explores the potential of maker pedagogy that is often more informal and that creates "practical, self-driven and solution-oriented" learning. This can be of considerable benefit in Higher Education and provide both fresh insights and sustainable pedagogic practices. Through an action research project of three cycles with first year undergraduate design students, he presents the reality for both a tutor introducing an alternative studio approach and the students' reactions to engaging with it. Through the three cycles the pedagogy shifts between being very open to much tighter, in what feels like an exploration of contrasts and conflicts between approaches. The article provides invaluable insights both into maker pedagogy itself and the affordances and constraints of introducing it into a more formal, structured, curriculum-based environment. The level of honesty and openness of the story told is impressive and this honesty makes this article a key contribution to understandings that are needed in considering how design education and pedagogy can develop and adapt to support future needs.

In *Effects of Curriculum Intervention on Divergent Thinking Abilities* Gökçe Ketizmen, and Hakan Keleş from Eskisehir Osmangazi University, Turkey continue the focus on Higher

Education and to the development of divergent thinking abilities in first year architecture students. The authors highlight the importance of divergent thinking skills in architecture education and present research aimed at identifying whether a one semester first year studio programme can support the development of such skills. The research was undertaken with 40 students and focused on a course entitled Thinking in Architecture Design that involved four design studio projects and also the Wallach and Kogan tests on divergent thinking, employed at both the start and end of the semester. The course placed emphasis on developing visual and verbal divergent thinking skills. The article reports in detail on both the projects and the pre and post-tests. In summary, the author's overarching findings indicated that the curriculum intervention led to improvements in both visual and verbal divergent thinking skills, particularly in the context of originality. The study highlights the value of engaging students in studio based divergent thinking courses early in their higher education experiences.

Design and Technology Education: An International Journal

28.2

# Guest Editorial: Building Research Capacity and Engagement in Design and Technology Education (BRACE), Special Issue

**Marion Rutland, University of Roehampton London, UK**
**Bhavna Prajapat, University of Brighton, UK**

Welcome to this Special Issue. It contains articles developed from papers presented by members of the Building Research Capacity and Engaging in Design and Technology Education (BRACE) community at the Pupils' Attitudes Towards Technology Conference (PATT39). This was held in St John's Newfoundland & Labrador, Canada from June 21-24, 2022.

BRACE was developed due to the initiative *The Knowledge Exchange* (KE) community, established by Dr Alison Hardy (Founder member and Principal Lead) and Dr Sarah Davies (Co-Lead) from Nottingham Trent University UK. KE is supported by the Design and Technology (D&T) Research Strategy Group, founded by Alison and hosted by the Design and Technology Association (D&TA), a national membership charity that promotes and supports D&T education in the UK. KE had observed a growing interest in the Design and Technology community for new research of relevance to, and applicable to D&T teachers' practice.

The overall aims of KE are to:

- Contribute to planned discussions where they can share ideas and the challenges involved when researching D&T education.
- Hear from national leaders, who will provide short thought-provoking talks about potential national research.
- Take part in workshops to develop conference papers into full journal articles.
- Present their research at a conference using 'live stream'.
- Contribute to the podcast series 'Researching D&T Education'.
- Produce summaries of their research to share with other relevant organisations.

The intention of this BRACE Special Issue is to bring together the research activities of a group of research-curious, aspiring and active D&T teachers interested in building their research capacity directly related to D&T education in schools. They were working alongside fellow academics, acting as mentors to research D&T issues that will improve pupils' learning and impacts on educational practice in schools and teacher education settings. Overall, the aim has been to identify and enable teachers and academics to work together to share ideas and identify and present research that is of interest to, and important to the D&T community in schools.

## Articles

We hope that you will enjoy reading these articles. They are examples of the BRACE community of teachers and their mentors working together to develop and present their research interests. They are directly related to current developments in primary and secondary D&T teaching in England.

The first article of this issue '*Teacher perceptions of critical thinking skills within English primary design and technology*' by Richard Brown, uses the phenomenological approach to explore English school teachers' viewpoints on critical thinking in primary design and technology practice. The supporting literature for this research takes a broad approach and identifies some of the issues and anxiety around teaching design and technology in the primary sector. The phenomenon of critical thinking is well explored, leading to a summation of why critical thinking is seen as a valuable educational activity for cognitive development, academic work and skills for employability, as well as, for individual wellbeing. The issue of critical thinking in design and technology education as a challenging area to fully implement in many classrooms is probed and discussed. Critical thinking can appear in many guises within the content of various design and technology activities, and it is discussed alongside cognitive development and creativity.

These issues are explored within the interviews, that are carried out as part of this research. An interesting methodology approach using 'Jamboard' is utilised to gather data from teachers in addition to the interviews. A 'word cloud' is created, based on a hierarchy of ways of learning to analyse the findings and teacher comments are used to clarify and support the discussion and analysis. As with any good research, the conclusions raise additional questions and identifies further important research areas concerning critical thinking that will enable the development of a more in-depth understanding of English primary design and technology practice in the classroom.

In the second article, '*Weaving the specialist material strands of design and technology together'*, Dr Sarah Davis, is focusing the 2014 revision to the National Curriculum for Design and Technology in England. These Orders introduced a recalibrated of the design and technology curriculum from the previous versions that have been developed, since the Education Reform Act (1988) that introduced a National Curriculum within England and Wales. Prior to 1989 subjects such as woodwork, metalwork, technical drawing and graphics known as craft, design and technology (CDT), together with home economics, needlework and electronics were all taught as separate subjects in secondary schools. The first National Curriculum in 1989 introduced design and technology (D&T) with these subjects taught by specialist design and technology teachers with the common requirement to develop skills in designing and making within a specific materials-technology knowledge base.

The directive in 2014 was to move toward a design centred approach, based on the use of mixed materials. Thus, each D&T teacher would be expected to know and be able to teach the full range of materials taught within design and technology. Sarah discusses the implications and challenges this brought for D&T teachers in the classroom. It is small scale research project, exploring two teachers' different views, perspectives and experiences. A range of emerging tensions are identified including 'material specialist teaching' and 'a design centred approach'. It explores how teachers with an often-limited range of specialist expertise will ensure children achieve comprehensive design and technology teaching with this multi-material approach. Sarah recognises that there is still an area of curriculum development for the current design and technology teacher where there is much more research to do.

A third article *Design and Technology Educators' Experiences of Competence, Relatedness and Autonomy with Educational Research'* by Matt McLain, Daniela Schillaci-Rowland, Kay Stables and Alison Hardy reports on the results of a survey of Design and Technology (D&T) educators, predominately based in England. The research looked for evidence of engagement by teachers in schools with educational research generally and more specifically, within Design and Technology Education. The survey was undertaken by the *Design and Technology Research Steering, Group (DTSRG),* established in 2021and sponsored by the professional *Association of Design and Technology Education.* Three research questions underpinned the study; to what extent are teachers of D&T currently engaged with educational research, is there interest in the development of support from the Design and Technology Association and where should it prioritise educational research?

This article builds on an initial analysis of the findings from the questionnaire at the Pupils' Attitudes Towards Technology (PATT39) conference, which focused on four survey questions. The views of past, present and future D&T educators engaged in educational research were explored. In the research 62% of the participants were involved in secondary D&T education and 20.2% in primary education. The majority (72.6%) of the international participants consisted of curriculum leaders (56.00%) and qualified teachers (35%). The majority of the responses came from qualified or trainee teachers, with 62.7%trained via the postgraduate route. 69% had not completed a postgraduate qualification with only 14.5% undertaking a full masters or a doctorate. 48.4% had been in service for up to 30 years and participants with more than 5 years' service.

An online questionnaire was used to collect data, the findings were analysed based on evidence of *competence, relatedness and autonomy* and explored to analyse and understand the D&T educator's interest and relationship with research. Most of the participants did not feel that they had access to relevant and high-quality D&T research readily available. The findings highlighted that teachers do want to engage in research, yet there was a general lack of confidence engaging in research and a lack of opportunities to network with other teachers, resulting in a feeling of disconnect between interest and action. It is noted that progress has been made since the survey was conducted, especially in primary schools and the formation of the D&T Research Strategy Group, hosted by the Design and Technology Association.

The final article of this Special BRACE Issue provides insight into secondary teachers' views of the recent development in D&T education in schools in England. The article, *How can teacher preparation in England within D&T minimise further decline of the* subject? by Claire Vickery, a secondary D&T teacher and Alison Hardy from the Nottingham Trent University UK discusses one part of data from a larger research project in England. The focus of the research is to identify factors that secondary school teachers of design and technology (D&T) in England consider may have contributed to the decline in entries at the General Certificate of Secondary Education (GCSE) examination for pupils aged 16 years. Essentially, the study was devised to ensure that the teachers' voices are heard and taken note of.

The study was conducted in two parts and included interviews, focus groups and an online survey. Part 1 of the research provided qualitative data from an online study, which informed the findings collated in Part 1. This article focuses on this data and the findings from an online survey in Part 2 of the research. The Research Question addressed was:

- How has the decline in D&T been impacted by decisions made at a national, classroom and individual level?

The teachers' responses from the participants were organised into 3 categories. They were the macro level or national government level, the meso or school level and the micro-classroom influences. Recruitment was largely undertaken through social media and the data collection was conducted virtually; it was acknowledged that this potentially limited the types of teachers that were participating with the project. The participants were qualified teachers with a teaching career of at least one full academic year on either a part- or full-time basis.

Overall, 26 factors findings were analysed against the 3 categories, and it was interesting to note that most of these were categorised as being outside the teacher's direct control. The most noteworthy factors were the impact of the English Baccalaureate (EBacc), a government-imposed performance and influences from the parents. It was noted by the teachers that there had been too many changes or unsupported changes to the subject, a disparity between teachers in the perception of what D&T is or should be, a lack of skilled teachers and a discrepancy between teachers in the way D&T is delivered within different settings. Also, there was the believe that there is little or no direction from national bodies about how to adapt current practices to the new curriculum content. It was considered that these issues can lead to differences in classrooms and departments, causing confusion for pupils and conflict amongst the staff. Both classroom teachers and heads of department agreed about the impact of the EBacc, and the parents influence but the teachers also thought that a lack of funding was having a negative impact on D&T.

The article recommended that further research was needed, especially at the nano level and parents and pupils' perceptions. This research was designed to acknowledge and emphasise the importance of the 'teacher' and reinforce the need for their voice to be listened to and considered. Although, the research is centred specifically on D&T education within England, it is hoped that it will prompt professional dialogue internationally.

Finally, this issue has a Book Review that has also been prepared as part of the BRACE project. The review has been conducted by Drew Wicken of the Co-op Academies Trust and Kay Stables, from Goldsmiths, University of London. The book, *Applications of Research in Technology Education: Helping teachers develop research-informed practice* is edited by P. John Williams and Belinda von Mengerson and is a collection of chapters prepared by recent doctoral graduates based on their PhDs. Each chapter provides an overview of the PhD and then focuses on the contributions their research makes to help teachers develop research-informed practice.

# Book Review

# A review of P. John Williams & Belinda von Mengerson (Eds) Applications of Research in Technology Education: Helping teachers develop research-informed practice

**Reviewed by Drew Wicken, Co-op Academies Trust, UK and Kay Stables, Goldsmiths, University of London, UK**

The book "Applications of Research in Technology Education" is a compilation of chapters drawn from recent PhDs in Technology Education written with the direct intention of providing insights from research conducted by technology educators from across a range of countries to support teachers in developing research-informed practice. It comprehensively explores the dynamic and evolving landscape of technology education.

Technology is pivotal in shaping societies, economies, and individual lives in today's rapidly changing world. Within these pages, readers will journey through the latest understanding of technology education, where researchers and educators explore cutting-edge strategies, best practices, and emerging trends. The book's chapters delve into the intricate interplay between theory and practice, showcasing how research findings can be translated into practical applications within classrooms, schools, and broader educational systems. By critically reviewing the diverse chapters contained in this compendium, our aim is to provide educators with valuable insights into the multifaceted landscape of technology education. This collection of chapters traverses a wide spectrum of perspectives and approaches to teaching in the field of technology education, thereby equipping educators with a comprehensive toolkit to enhance their pedagogical practices.

These chapters offer an array of educational resources that cater to both novices and seasoned practitioners in the realm of technology education. Whether you're embarking on the journey of teaching this subject for the first time or possess a wealth of experience, engaging with this book's articles promises to be a rewarding endeavour. Moreover, it fosters a continuous learning ethos, enabling educators to adapt to the evolving demands of the educational landscape and equip their students with the skills and knowledge necessary to excel in an increasingly technology-driven world.

In the first and last chapters, the editors provide their own overview and conclusions with respect to the chapters included. We have focused on the 15 research chapters in between. The textual composition under scrutiny is structured into three distinct segments, denominated as "Perceptions and Practices," "Skills in Designing," and "Curriculum and Pedagogy." Within the confines of these delineated sections, a compendium of scholarly investigations and analyses is presented, all devoted to the comprehensive examination of the overarching thematic precept of technology education. These thematic sections encompass a vast expanse of subject matter, facilitating a profound and multifaceted exploration of the subject matter from an array of distinct vantage points.

Starting with Perceptions and Practices, the first of the studies is by Paul Mburu, Roehampton University UK. His chapter ***Leadership Perceptions in Design and Technology Education,*** presents an intriguing study that delves into the intricacies of leadership tools within a design and technology department, focusing on enhancing the subject's visibility among stakeholders. The investigation revolves around six incumbent subject leaders operating within various secondary school settings. Mburu employs diverse datasets to meticulously assess and juxtapose the efficacy of distinct leadership styles and tools. The study unravels a spectrum of perspectives concerning the utility of available leadership tools, shedding light on their varied deployment strategies.

Significantly, Mburu's research underscores the imperative of establishing a symbiotic link between classroom practices and team dynamics. This alignment is posited as a pivotal mechanism for augmenting overall team effectiveness, thereby positively influencing teaching, learning, and subject vision development. Notably, the chapter's findings transcend theoretical discourse; they hold practical relevance for individuals assuming subject leadership roles, both neophytes and seasoned practitioners. The chapter offers invaluable insights that are instrumental in cultivating a coherent and sustainable leadership style within the precincts of a design and technology department.

Mburu's work contributes substantively to the scholarship on educational leadership, providing a nuanced understanding of its dynamic interplay within a specialised pedagogical domain. Delving into the intricate nuances of leadership tools and strategies it enriches our comprehension of the multifaceted dimensions underpinning effective leadership in the realm of design and technology education.

Moving onto the next piece of work, Dawne Irving Bell of Edge Hill University UK looks at ***The formation of Science, Technology, Engineering, and Mathematics teacher identities: Pre-service teacher's perceptions*.** Irving Bell's chapter has two major focuses. The first provides an account of the research undertaken for her PhD. As the title indicates, the research focuses on influences on the formation of teacher identities in pre-service STEM teachers. The account of her research is clear and straightforward and impressively accessible as she outlines the *what*, *how* and *why* of her study. Through her account of choice and use of research methods she provides clear guidance that de-mystifies research processes. Exploring the formation of teacher identities through semi-structured interviews with pre-service teachers she highlights how identities are influenced by those that taught them – both 'good' and 'bad' teachers. Collecting further data as pre-service teachers progressed through their courses, the focus shifts to the negative impact insufficient subject knowledge has on pedagogic approaches, often creating traits identified in 'bad' teaching experienced as pupils. My personal reflection took me back to my own school days, realising the lifelong impact of teachers who became my role models and just one 'bad' teacher who confirmed my intention as a 14 year old to become a teacher – to be better than her! The second focus is on negative impacts on pre-service teachers' professional identities, triggered when in situations where, for example, they had or perceived they had insufficient subject knowledge. Drawing from her research data she provides suggestions for how experienced teachers can support others to develop strong professional identities.

***Exploring Teachers' Perceptions and Strategies for Curriculum Practice in Technology Education*** by Elizabeth Reinsfield of University of Waikato, New Zealand, is the next area of research**.** Reinsfield's investigation delves into educators' perceptions of curriculum and its application for students. The research unveils compelling parallels between the theoretical foundations of curriculum and its practical implementation, akin to the persistent challenges witnessed with the English National Curriculum over the past decade. Notably, the study elucidates a prevalent inclination among educators to prioritise pragmatic outcomes in response to declining student engagement, thereby diverting focus away from the cultivation of specialised knowledge. Consequently, this shift in pedagogical emphasis transitions from immersive problem exploration and response, as embodied by the iterative design process, to a more knowledge-centric transmission approach.

Moreover, the research findings underscore a substantial enhancement in student engagement when learners actively shape the decision-making processes related to their educational journeys. This chapter accentuates the significance of ensuring that all stakeholders comprehensively understand the intricacies involved in curriculum planning. Reinsfield's work contributes to the discourse on effective curriculum development and its implications for educational engagement and outcomes by illuminating the challenges surrounding curriculum theory-practice alignment and the potential divergence towards knowledge transmission.

In the last chapter of "Perceptions and Practices" Andrew Doyle's piece focuses on ***Rhetoric to Reality: Understanding enacted practice in Technology Education*****.** Doyle, whose research took place while at KTH Royal Institute of Technology, Sweden, opens up the thorny challenge of unpacking the rhetoric of how Technology Education is perceived at an international level in contrast to the reality of what happens in the classroom at a local level – in the case of his research in the context of the Irish National Curriculum for Technology Education. Focusing on the enacted practice in classrooms in the space between beliefs about the broader nature of Technology Education and the professional knowledge base of an individual teacher he highlights the conflicts and conundrums that many technology teachers experience in considering what happens on a day to day basis. He highlights aspects that impact on this from National Curricula to assessment strategies, while maintaining his research focus on enacted practice including interviewing teachers reflecting on learning activities in their day to day teaching. Three overarching conceptions emerged: obtaining knowledge and skills for application such as woodworking skills to apply when making, gaining the ability to act in a technological way, for example learning a technological skill for future use and having the ability to think critically about various and new technologies. The research doesn't present answers but opens up space for reflection, possibly for a teacher to consider their own enacted practices, what lies behind them and how their reflection could impact on their future practice. The chapter is more philosophical than practical. It certainly provides food for thought.

Chapter 6 is the first within the "Skills in Designing" section where ***Enhancing Elementary Teacher Practice Through Technological/Engineering Design-Based Learning*** by Anita Deck, Concord University, USA, opens the next theme of the book. Deck's study investigates the significance of purposeful and comprehensive Continuing Professional Development (CPD) for primary educators in teaching STEM subjects, particularly employing Design-Based Learning (DBL) through Technological/ Engineering (T/E) tasks across six elementary schools. The research is structured around three primary phases. Firstly, baseline understanding of T/E DBL's integration in elementary teaching is gauged. Subsequently, CPD sessions are provided to enhance participants' DBL knowledge for STEM instruction. Lastly, participants' feedback on CPD impact and classroom implementation is gathered. The study concludes that T/E DBL-oriented CPD positively enhances teachers' grasp of STEM topic delivery and alleviates pedagogical concerns. This reinforces the case for subject-specific, in-school CPD, particularly for primary educators with limited post-training CPD exposure. Additionally, Deck's findings suggest enhanced student comprehension through T/E DBL application, advocating for its broader curriculum integration. School CPD coordinators will find valuable insights in Deck's work to optimise CPD models for supporting holistic student understanding in various subjects.

Following on from Deck's work, Dave van Breukelen, from Fontys University of Applied Sciences for Teacher Education, the Netherlands, investigates ***Teaching Science Through Design Activities***. Breukelen explores Design-Based Learning (DBL) within an interdisciplinary setting – in his case science and design. He highlights the value of DBL for skills learning but its lack of success for conceptual learning through research to identify strategies within DBL that support the learning of both concepts and skills. Four studies were undertaken, the first two were exploratory using a Learning By Design (LBD) approach, the second two taking what was learned from the earlier studies to develop pedagogic strategies aimed at developing both skills and concepts. His findings enabled the creation of a model for interdisciplinary design that opens up, makes possible, provides guidance and suggestions for teachers to engage in interdisciplinary teaching. Clear pedagogic strategies, based on his research outcomes, are presented giving much for teachers to reflect on and engage with. Principles, practical processes and clear and detailed guidance are highlighted as an 'overall picture' not a mandatory approach. Recognising pitfalls and challenges, the model provides plenty of depth and quality to reveal the value and possibilities of interdisciplinary design based learning and teaching. His aim is to improve learning processes and expand DBL supporting a continuum of teacher development from being a restricted to extended professional. In his words "be open minded, investigate opportunities, embrace iteration, and collaborate with colleagues and experts". Tackling interdisciplinarity in education is brave. This chapter provides a rationale and route to bring disciplines together. It provides the impetus to take an open approach within technology education as well as strong support for integrated STEM or STEAM projects whilst tackling the sticky challenge of enhancing the learning of skills and concepts.

The research in Chapter 8, ***Human-centred design pedagogies to teach values in Technology Education***, by Neshane Harvey and Piet Ankiewicz, University of Johannesburg, South Africa, focuses on using co-design as a pedagogic strategy in university level fashion design. The research was undertaken with Year 1 fashion students and explored the pedagogic value of role play when students worked as pairs, one taking the role of the designer and the other taking the role of the user, collaborating as co-designers to enable a 'mindshift' away from the norm of the 'hero designer'. Data was collected from the students and also from observations of two design educators. The results indicated an impressive shift as the students quickly moved towards an equilibrium as the 'users' became key to inspirational ideas and the designers demonstrated a level of empathy as a symbiotic relationship developed. There was also impact on the educators as they were forced to consider the value of more traditional design approaches. Although set in Higher Education fashion design education, the approach taken to the research and the findings that emerged could be relevant to younger age groups and also to design areas other than fashion. The role play of the students clearly helped them develop deeper understandings of the potential of users and designers collaborating – and as a pedagogic structure the potential for creating a more critical and empathetic approach to designing is very high. Teacher practitioners of any age group, and in any context of user-centred design could be inspired by the pedagogic approach. While thought would be needed to adopt it, at its heart it has a practical and simple idea of people working together and valuing each other's ideas and views.

In chapter 9, ***Using Engineering Design in Technology Education,*** Euisuk Sung, New York City College of Technology, USA and Todd R. Kelley, Purdue University, USA report on a study that investigates the utilisation of the engineering design process in technology-based education. The research seeks to elucidate the purpose and mechanisms underlying the adoption of this process, particularly in aiding students' resolution of technical problems. The researchers analysed videotaped lessons spanning five academic years in Midwest US elementary schools to address these inquiries. Despite a prevalent belief among technology educators in a linear approach to the design process, it is acknowledged to be inherently iterative due to multifaceted influencing factors. Employing Halfin's revised coding system from the 1970s, the study categorises design-related tasks for statistical analysis, encompassing defining problems, analysing, predicting, questioning, designing, managing, and modelling (DF, AN, PR, QH, DE, MA, MO).

The analysis of collected data reveals two distinct pathways in completing design work: Questioning - Designing - Modeling - Managing, and Questioning - Designing - Predicting - Managing. Time allocation to various stages highlights that designing receives predominant attention, constituting approximately half of the students' engagement time. Nevertheless, even substantial emphasis on design does not guarantee an optimal design strategy. Sung and Kelley emphasise that the engineering design process should be perceived as an iterative endeavour rather than a fixed sequence, facilitating extensive exploration of design challenges. This research underscores the need for educators to adopt a more iterative design process model, promoting learner creativity and innovation in response to complex challenges. It contributes to enhancing pedagogical practices in design-focused education.

In ***Assessment of Real-World Problem-Solving and Critical Thinking Skills in a Technology Education Classroom*****,** Susheela Shanta, Governor's STEM Academy at BCAT in Roanoke County Schools, USA, provides a slightly constrained account of her research. Once again the research is set in the context of STEM, Problem Based Learning , Design Based Learning and authentic contexts but the research itself is more narrowly focused. There are clear and valuable intentions behind the research which aims to assess learners' application of higher order thinking skills and science and maths concepts in an authentic context in a design-no-make challenge. The research also focuses on developing an assessment rubric that scores learners' responses to the challenge presented, which could form the basis of rubrics developed with similar assessment intentions. There are two main research findings. The first is that the use of design-no-make in the learners operating within a design based learning pedagogy was higher than those in a "traditional" classroom setting.  This is good news for those of us who believe in design based learning, but it is frustrating that we have no detail of the comparative set. Second is that learners applying science and maths concepts beyond the classroom and in an authentic, real-world context scored more highly than those in a “traditional” classroom setting. Again this is a positive outcome and adds to other research that explores the impact of contextually based performance. But, again, the comparative “traditional” setting has no descriptive context, just the lower scores achieved. In addition is a concern about the choice of the “real-world” problem, set in “a village in a third world country” that provides a somewhat worrying stereotype. This is surprising when, later in the chapter, more appropriate and helpful suggestions on creating authentic contexts are provided. The chapter is interesting but also tantalising because of the details not included. However, readers who want to know more could do so by accessing the full PhD.

Chapter 11 ***The Importance of Spatial Ability Within Technology Education*** provides insight into a further PhD undertaken at KTH, Sweden**,** by Jeffrey Buckley and Niall Seery, Technological University of the Shannon, Ireland, Donal Canty, Limerick University, Ireland and Lena Gumaelius, Mälardalens Högskola, Sweden, is the last piece within the “Skills in Designing” section of the book. The nature and importance of spatial ability is one not frequently researched specifically in the context of technology education. As the authors comment, spatial ability if often related to STEM but focused on maths, science and engineering. However, the research in this chapter highlights the potential of technology education pedagogically supporting the development of spatial ability and the extent to which technology education enables perspectives on spatial ability that focus on aspects beyond the need for disciplinary knowledge acquisition, placing emphasis on knowledge application. The dual concepts of *crystallised intelligence*, which links to acquired knowledge and *fluid intelligence*, such as that needed for novel problem solving provide insight into ways in which technology education has specific value in developing spatial ability. Fascinatingly, they also reveal that fluid intelligence is the dimension of intelligence that correlates most closely with general intelligence.

Four research studies on spatial ability were conducted, each presenting different perspectives on aspects of spatial ability and how these could influence improvements in learning and tech in in technology education. Practical approaches to developing spatial ability provide a range of pedagogical approaches, including the concept of “spatialising the curriculum” by employing within existing curricula spatial symbolic systems such as maps and graphs, making use of analogy, gesturing and further ways of visualising thinking. The chapter does delve into some complex concepts, but in parallel presents a positive, uplifting perspective showing ways in which technology education can be a key lead in developing this critical aspect of learning and reasons why technology education should not be marginalised within STEM.

***Appropriate Use of ‘Assessment for Learning’ Practices to Enhance Teaching and Learning*** by Chandan Boodhoo, Mauritius Institute of Education, opens the final section of the book “Curriculum and Pedagogy”. Boodhoo’s research delves into a critical area of educational discourse: the implementation of formative assessment, also known as 'assessment for learning,' in the context of design and technology education. While extensive literature exists on formative assessment in education, its application in design and technology has received limited attention. Boodhoo's study explores how formative assessment techniques can be effectively employed to support student learning in this domain. The research primarily scrutinises the utilisation of 'assessment for learning' strategies within design and technology and investigates the decision-making processes teachers employ in integrating these strategies into their instructional practices.

Utilising a mixed-methods approach, Boodhoo employs various research techniques, such as lesson observations and interviews, to gain insights into how three Mauritian teachers incorporate 'assessment for learning' in design and technology education. The study's outcomes, however, reveal a discouraging picture characterised by teachers' limited proficiency and motivation in implementing formative assessment in their classrooms. A notable deficiency was identified in the teachers' questioning techniques, marked by a preference for simplistic, closed-ended questions over inquiries that could uncover student misconceptions. Boodhoo observes that these teachers seemed 'ill-equipped' to appropriately time and structure questions to engage students and gauge their learning progress effectively.

Nevertheless, it is essential to note that these findings may not present a comprehensive reflection of formative assessment practices within design and technology education. The study's restricted sample size suggests that a broader investigation, encompassing diverse geographic contexts, might yield more favourable outcomes, revealing the effective deployment of formative assessment strategies in design and technology instruction.

***Integrating Design and Technology with Entrepreneurship in Lesotho*** by Nthoesele Mohlomi, National Curriculum Development Centre, Lesotho is the next chapter within the final section of the book. This chapter provides insight into an ambitious and progressive Design and Technology (D&T) National Curriculum reform for primary and secondary education in Lesotho. The focus is developing a curriculum that integrates D&T education with Enterprise education. Interestingly, D&T is located in the Creativity and Entrepreneurship learning area in Lesotho. Also that the reform was phased in, starting in 2009 with Grade 3, and having the approach throughout all grades by 2020. As with many countries, D&T evolved from craft education. Emphasis within the reform includes problem solving within design activities, developing technical, manipulative and graphical skills and awareness of Lesotho heritage and culture. Entrepreneurship promotes nurturing passion and talent, enabling learners to be visionary, risk takers, team players, creative, innovative and passionate.

Research questions asked what is the nature and purpose of D&T, why integrate with Entrepreneurship and what are the teachers’ roles in implementation. A qualitative process drawing on interviews, observations and written documents was used. Participants were selected from the 70 schools piloting the new approach. It emerged that teachers were positive about the vision for the reform but that implementing it was challenging. The Curriculum reform highlighted projects, themes and scenarios that explored real-life contexts and integrated D&T’s focus on production environment and evaluation with entrepreneurships’ focus on creativity, innovation and being socially and economically productive. The teachers’ role shifted from conveying knowledge to nurturing the learners’ skills, talents, attitudes and values. Achieving this shift presented challenges such as class sizes of 40 and more and a lack of training to support moving from disciplinary to transdisciplinary approaches. But teachers also gained insights into learners, like how exploratory and resourceful they can be, utilising local materials, selling artefacts produced in class and organising events. Based on findings the researchers identified key strategies to support teachers but highlighted systemic challenges such as ongoing emphasis on summative examinations as academic goals.

The chapter provides an important case study of curriculum change. Teachers, researchers and curriculum developers across the globe will recognise the ambitions and challenges of what is effectively on ongoing story that is fundamentally educationally uplifting.

Chapter 14, ***Teaching Technology in a Play-Based Preschool—Views and Challenges*** by Pernilla Sundqvist, Mälardalen University, Sweden, presents a study examining the delivery of technology education in Swedish preschools, involving both preschool teachers and childcare attendants to provide a comprehensive perspective on the preschool curriculum. Utilising questionnaires, group interviews, and observations, the research seeks to elucidate their viewpoints, the subject matter covered, and the characterisation of individuals involved. The study reveals that preschool teachers characterise technology education in six distinct ways, leading to various categorisations. This diversity poses a challenge, resulting in varied approaches to the subject, thereby introducing inconsistency in children's education. A contributing factor to these inconsistencies, as Sundqvist notes, is the Swedish language itself. In Swedish, the words 'Technology' and 'Technique' are represented by the same term, "Teknik." This linguistic overlap can lead to confusion, particularly in distinguishing technology from other subjects like science when delivering the technology curriculum.

To address this challenge and ensure uniformity in technology education, it is imperative that staff become mindful of these distinctions. Sundqvist offers a straightforward guideline: anything created by humans constitutes technology, while the study of natural phenomena falls under the purview of science. This research underscores issues that transcend national boundaries, highlighting the importance of schools comprehending the subject matter before imparting technology education. It emphasises the necessity of providing a clear and consistent understanding of technology to enhance children's comprehension of this critical field.

**Applying a Culturally Responsive Pedagogy to Promote Indigenous Technology in Teaching Design Skills by** Richard Maluleke, Nkone Maruping Primary School, South Africa and Mishack Gumbo, University of South Africa, is a fascinating piece. The study focuses on indigenous technology in lessons and offers valuable insights into promoting equity in technology education. It highlights how many Western-oriented curriculums tend to perpetuate a specific design process—design-make-evaluate. In contrast, indigenous communities often create artefacts through experiential design rather than adhering to a prescribed design sequence.

The research employs semi-structured interviews with various stakeholders and lesson observations to explore how indigenous pedagogies are integrated into South African school lessons. Their findings emphasise that acknowledging learners' diverse cultural backgrounds can heighten students' interest in the subject. The authors advocate for culturally relevant pedagogy (CRP), asserting that teachers' reflection on their students' cultural diversity can significantly enhance educational outcomes. Furthermore, CRP in technology lessons can introduce learners to alternative design approaches beyond Western conventions.

This study illuminates the Western-centric foundations of many school curriculums. It underscores the importance of teachers incorporating their students' cultural backgrounds into technology lessons. Decolonising the curriculum is a prevalent topic in contemporary education, and this study provides practical insights into how technology educators can approach this task. It demonstrates how Western ideals are deeply embedded in curriculum planning and advocates for the challenge of offering students a culturally enriched technology curriculum. By recognising and incorporating indigenous and culturally diverse perspectives, teachers can better prepare students for a globalised world and promote a more inclusive and equitable learning environment.

The final chapter in the book is ***Implementing Digital Tablet Activities in Swedish Preschool Education***, by Anna Otterborn, Örebro University, Sweden and Konrad Schönborn Linköping University, Sweden. This chapter focuses on pre-school environments in Sweden, exploring teachers' use of digital tablets in technology education and of implementing programming in pre-school practice. In Sweden teachers are expected to use digital tools as part of their pedagogy including with small children. This is another uplifting chapter that provides a clear focus on the positivity of the early years teachers and the enthusiasm of their young learners. The research focused on three overarching questions: how teachers use digital tablets in pre-school educational practice, how they do this within technology education and how they implement programming in their practice. Research data was collected via an online survey that afforded both quantitative and qualitative data. Within the overarching questions they also explored links to STEM and the programs and apps that were used. The major uses of digital tables were within technology, science, language and mathematics, focusing on documentation and reflection, cooperation and values, critical thinking, thematic approaches and fact searching. It was clear from the research that teachers (and their learners) were enthusiastic and innovative, blending the use of digital technology within the heartlands of early years learning. The chapter includes a wealth of information in respect of this and includes a vignette that illustrates this beautifully describing a project where six year olds prepared for a city walk via a projected digital map that allowed them to identify the route, landmarks etc and following taking the walk, the activities that followed including painting a large, illustrated map on the classroom floor using pictures taken on their digital devices, making some of the buildings and programming a Blue-Bot to navigate the route. Findings also showed that, whilst innovative, brave and enthusiastic, teachers still need clearer guidance and support. The authors propose key areas for practical approaches and advice including promoting digital competence and work strategies; preventing a 'digital divide'; choosing suitable applications; focusing on purpose, interests, needs and goals; dedicating time and holding teacher workshops. The pedagogy illustrated in this chapter is of value for educators at all levels demonstrating foundations of learning and teaching that we can all learn from.

This assessment of Williams and von Mengersen's publication, delving into contemporary research within the domain of technology education, aspires to serve as a valuable resource for educators in their daily practice. One of the primary challenges faced by technology educators when engaging with research pertains to the small number of subject-specific studies that can effectively enrich their pedagogical approach. Nonetheless, the book unequivocally underscores the wealth of research available across a spectrum of diverse topics within this discipline. Whether you choose to peruse the entirety of the book or concentrate on select chapters, it is our earnest expectation that both this review and the book itself can offer substantive insights to enhance the instructional practices of educators, ultimately fostering optimal outcomes for our students.

Design and Technology Education: An International Journal

28.2

# Teacher perceptions of critical thinking skills within primary school design and technology

**Richard Brown, University of Cambridge, UK**

## Abstract
Critical thinking skills and creativity have been lauded by many as key attributes sought from prospective employees for the future workplace in an ever changing world. Furthermore, a review of existing literature suggested the prevalence of critical thinking skills within design and technology (D&T) tasks. This study aimed to garner the perceptions of primary school teachers in the UK and establish, from a practitioner's viewpoint, whether critical thinking skills were evident within their classrooms during D&T sessions. The interviews followed a phenomenological approach and identified commonalities and differences between the teachers' viewpoints as they described the phenomena they had experienced. The eight interviewees were from different schools in different areas of the UK and ranged from experienced teachers to early career teachers. Teachers were asked about their experiences of teaching D&T before completing a hierarchal ordering exercise of skills they perceived were gained from D&T activities in primary schools. The data produced experiences, thoughts and opinions about teaching design and technology in primary schools and teacher perceptions of the role of critical thinking within them. Analysis of the interview transcripts identified critical thinking throughout the responses and categorised three main themes around the teaching of design and technology in primary schools: approaches, attitudes and outcomes. This study suggests that, for primary teachers to develop their pupils' critical thinking skills within design and technology, and thus develop technological literacy, there are issues that need addressing at both leadership and classroom levels such as training, resourcing and leadership priorities. Nevertheless, teachers interviewed in this small scale study confidently believed that primary school pupils benefit from promoting critical thinking within D&T activities.

## Keywords
Design and Technology, Critical Thinking, Teacher Perceptions, Primary/Elementary Education

## Introduction
### Context
This article has been taken from a study based in the UK, interviewing teachers from English primary schools where Design & Technology (D&T) is taught to pupils aged 4-11 and the subject is part of the statutory national curriculum (DfE, 2013). The study was a Master 's level dissertation and had three research questions, one of which was related to teacher perceptions of critical thinking in D&T activities. Aspects of this article, such as summarised sections of the literature review and results, have been drawn from the dissertation but the focus of critical thinking is central to the discussion.

Through delivery of D&T projects across a variety of age ranges and schools across the UK, anecdotal evidence suggests that children, and teachers, enjoying D&T sessions. Sessions taught to trainee teachers also advocate an enthusiasm for the subject. However, this gathering of thoughts and perceptions is clearly not based upon an empirical study. The main motivation of this study therefore, was to develop a deeper understanding of the perceptions of teachers and identify commonalities and differences.

The literature review of the study initially considered the educational benefits of D&T. One of the key conclusions from the research was that there was less research about D&T in general within the primary sector but research available demonstrated that teacher attitudes towards the subject can vary. Although work to investigate the positive links between primary and secondary D&T has been instigated by Hardy and Gomersall (2017), the concern in the primary sector is that “Just the words Design and Technology (D&T) make some people nervous.” (Newton, 2005, p.1) There is also an issue about teacher anxiety when teaching D&T. There are health and safety considerations, it is a subject that is unlike others and a lack of subject knowledge, possibly stemming from a lack of Continuing Professional Development (CPD), affects teacher confidence. Research by Kimbell (2008, 2017), Stables (2012), Bell et al. (2017) highlight the concerns that D&T, albeit relating predominantly to secondary education, is becoming seen as a subject which is one that “has effectively been relegated to the confines of a subject considered to be less desirable and arguably non-academic by educational policy” (Bell et al., 2017, p.540).

However, as Bell (2016) attests, children enjoy the subject and there is a wider contribution to education that D&T provides as it allows children to explore, make mistakes and develop the often-lauded growth mindset (Dweck 2012) approach to solving problems. To support this view, the inventor and entrepreneur James Dyson suggests: “Design and technology classes should be about breaking the rules and learning from mistakes.” (Dyson, 2005, p.34).

Furthermore, from this initial research, key words such as creativity, problem solving and critical thinking emerged and were investigated and researched in further detail. The terms creativity and problem solving are both well known by primary school educationalists and teachers often have well defined views and opinions of them within their own teaching pedagogy. Critical thinking, however, is perhaps less commonly used and an area which required further research into the literature before compiling the research questions.

**Defining critical thinking**

Critical thinking is a commonly used term used to describe problem solving or independent thinking, however many academics state that it is hard to distinguish with one clear definition (Ab Kadir, 2018; Wei, 2020; Yang & Chung, 2009).

The Organisation for Economic Co-operation and Development (OECD) defines critical thinking as a “mainly inquisitive, a detective way of thinking” and creative thinking as an “imaginative, the artist way of thinking” (Vincent-Lancrin et al., 2019, p.27). The analogy of the critical thinking detective and the creative thinking artist is potentially useful to distinguish the two but there is a multitude of research around both and many other definitions.

Willingham (2020) suggests that critical thinking is a combination of novel thinking, self-directed thinking and effective thinking and Chew et al. (2020) as “seeing both sides of the issue, reasoning, deducing and inferring conclusions” (p.1). Lai (2011) encourages the view that defining critical thinking depends upon whether it is during the process, the end product or as a stand-alone higher order thinking skill. Barnett (1997) also has the view that defining the concept of critical thinking is dependent upon how it is used. The most widely viewed definition is the work of Richard Ennis who suggests that critical thinking is “reflective thinking focused on deciding what to believe or do” (Ennis, 2018, p.166)

The Cambridge University Press (CUP) released a series titled Life Competencies Framework (2019), with the aim to prepare students for the changing world ahead. Originally designed for English language development, critical thinking is sub-divided into three categories:

- Critical evaluation: analysing information and identifying patterns
- Analytical framework: judging which arguments, ideas or options and then solving problems
- Synthesising ideas: generating new ideas from others

Whilst the OECD detective is a simple analogy and Ennis’s definition is widely used, this study used the CUP model as a straightforward way to define critical thinking to participants during the interview.

**Justifying the importance of critical thinking**

The OECD reports that critical thinking and creative skills are two skills that are necessary for the future workforce and that critical thinking in particular can “contribute to a human well-being and to the good functioning of democratic societies” (Vincent-Lancrin et al., 2019, p.18). Later in the report the authors suggest that critical thinking has become even more vital “in a digital world in which a multiplicity of facts, views, theories and assumptions compete” (2019, p.20).

It could be said that with an assessment system that promotes retention of knowledge, the development of critical thinking and creativity in schools is less central. An independent panel, led by David Sainsbury, states “our education and skills system is failing to develop the skills employers seek” (DfE, 2016, p.22). Furthermore, Jagannathan et al., stated that future employers seek employees who demonstrate skills “such as creativity, effort and initiative, critical thinking and design thinking and negotiation skills which contribute to complex problem-solving in the workplace” (2019, p.2).

This can be supported by research from around the world. Trilling and Fadel (2009) in the USA state how critical thinking can “unlock a lifetime of learning” and has “become an increasingly important feature in the educational policies of many countries.” Ab Kadir (2018) discusses the Australian curriculum and the inclusion of critical and creative thinking as a tool for future industry. A Chilean based study by Cáceres et al. (2020) cite and agree with Butler et al. (2017) suggesting that “mastering critical thinking is a better predictor of successful life decisions than other factors, such as intelligence.” (2020, p.1)

In addition, world leaders have also recognised the importance of critical thinking. President Barack Obama challenged education leaders “to develop standards and assessments that don’t simply measure whether students can fill in a bubble on a test, but whether they possess 21$^{st}$ century skills like problem-solving and critical thinking and entrepreneurship and creativity.” (2009 p.1).

The ability to think critically, to evaluate, infer and deduce can be central to developing knowledge and understanding at a greater depth standard. Certainly, reading and maths end of key stage tests require a degree of detecting skills and in this regard critical thinking can appear to be an important skill that can be utilised in a number of situations. However, this study concentrated upon the development of critical thinking within the subject area of design and technology, and in particular within primary schools.

**Critical thinking and D&T**

There are many researchers that link the metacognitive skill of critical thinking as being synonymous with the subject of design and technology. Rauscher and Badenhorst (2021 p.1) state that teachers are more likely to "encourage critical thinking in design and technology". Whilst welcoming the suggestion that critical thinking skills can be linked with D&T, Ab Kadir (2018) would argue that critical thinking skills can be developed through many other subjects by utilising teacher expertise and skill.

Nicholl (2017) provides a practical example of critical thinking within D&T sessions with young people. He suggests that by designing for a purpose through a clear design brief, pupils will need to be empathetic to their client's needs and that empathy is "embodied within an overall disposition to think critically." (p.156). As an additional example, Wei (2020) analysed the design journals of junior high school students to find evidence of critical thinking and was able to identify critical thinking processes during problem exploration.

Spuzic et al. (2016) determined that within engineering, criticality and creativity are valuable skills. Whilst creative thinking can be seen as imaginative and critical thinking more analytical, both have worth in design and engineering. The report cites Adriansen's (2010) table that attempts to differentiate the two cognitive skills (Table 1). Mulnix (2012) concurs with the above and that there should be a clear distinction between creative thinking and critical thinking as they are not "equivalent".

***Table 1 Idealised differences between criticality and creativity (Taken from Spuzic et al 2016, p.5)***

| Creativity | Criticality |
|---|---|
| Imaginative | Rational |
| Non-judgemental | Evaluative |
| Generative | Selective |
| Holistic | Analytical |
| Constructing | Deconstructing |
| Transcending the framework | Within the framework |
| Open to serendipity | Work systematically |
| Iterative process with detours | Linear process |

Whilst the above research suggests that critical thinking can be found within D&T activities, the vast majority of research considered within this study is based within secondary schools (aged 11-16) or within further and higher education. Little evidence and research have been found within primary schools and this prompted a further research avenue of when critical thinking could, or should, be taught.

**When to teach critical thinking**

Both Facione (1990, 2000) and Rauscher and Badenhorst (2021) build upon the practicalities of teaching critical skills to children and young people and the 'dispositions' to developing this higher order thinking skill in the classroom. Facione (2000) promotes 'habits of mind' and suggests that this type of thinking is valuable not just for older students but can also be taught to younger children at primary level. Chew et al. (2020) agree that critical thinking "should be encouraged and instilled in students starting from a young age" (2020, p.249) and Gelerstein et al. (2016) suggest primary schooling is the most advantageous time to teach critical thinking (p.40). Willingham concurs, and after working with both older and younger children, additionally states that "children are more capable than we thought" (2020, p.45).

Whilst not necessarily directly opposing the above, Rauscher and Badenhorst (2021 suggest that the level of problem-solving skills is much higher in secondary education and that teachers in this sector, particularly technology teachers, are more likely to promote and utilise critical thinking skills with learners in their classes. Hennessey and Murphy (1999) concur in a similar fashion but also suggest that this is because more studies have been secondary based than at primary.

**Best practice for critical thinking**

Whilst the literature may demonstrate the benefits of critical thinking and it can be taught to younger pupils, the 'how' to teach it is more challenging, particularly at a primary school level. Willingham (2000) suggests a four-stage strategy to introduce and develop critical thinking skills with children and young people.

- Identify critical thinking skills in each domain: skills are subject and skill dependent.
- Identify the domain content students must know
- specific knowledge is required before considering it critically.
- Sequencing critical thinking skills: a sequential development of thinking skills.
- Revisiting critical thinking skills: retention of critical thinking skills.

This four-step programme could be applied to many learning programmes but it highlights that just exposing students to opportunities for critical thinking is not enough; it needs to be considered in a longer term and revisited over a period of time. To concur, Halpern and Riggio (2002) not only suggest that these skills should be taught, but also that they should be nurtured over a period of time through a process of modelling and leading. They then produced a series of journal reflections and questioning techniques within the book to aid the reader develop their own critical thinking skills.

With this in mind, educationalists might be considering how to identify and ensure that critical thinking approaches are successful. Gelerstein et al. (2016) suggest that "not enough work has been done to measure these skills in a classroom setting" (p.40) but agree with Willingham (2020) that the challenge with assessing critical thinking skills is that it is very subjective. Erikson and Erikson (2019) suggest three reasons why assessing critical thinking is so challenging. The first is also subjectivity and interpretivism; the second being that measuring learning outcomes is difficult to define and lastly that by defining critical thinking educationalists may limit the "ceiling for student ambitions" (p.293).

Nevertheless, Stupple et al. (2017) created a Critical Thinking Toolkit (CriTT) which they stated would measure student attitudes and beliefs about critical thinking and proposed would be able to determine levels of critical thinking within higher education. Likewise, Bensley et al. (2016) produced work to determine successfulness of measuring critical thinking skills but the biggest issue would be translating either into practice within primary schools.

Through the literature review, the emphasis has been on critical thinking: what it is, the benefits and the links with D&T. This area of learning has differing facets depending how and where it is used. Critical thinking skills within industry has been shown to be very desirable and there are design and engineering companies actively seeking potential employees with these skills. However, the role classroom practitioners have in this warranted further investigation and consequently three research questions were derived from the literature.

Throughout the critical thinking literature, a lot of research relates to secondary and, certainly the majority, to higher education. Considering the possibility of exploring critical thinking within primary schools and to garner the ideas and perceptions of primary school teachers would therefore be of interest. Cáceres et al. (2020) study state that "studying critical thinking from the teacher's perspective is key" as the work by teachers is often overlooked. As this area of cognition is potentially prevalent within D&T activities, it was consequently chosen as a key line of enquiry to consider teacher perceptions of D&T and their thoughts regarding critical thinking.

With the above in mind, the key research question, and emphasis of this article, evolved: '*What are teacher perceptions of critical thinking in primary schools within design and technology sessions?*'.

## Methodology

To understand the perceptions of teachers, interviewing was chosen as the main source of collecting data. This would entail a requirement to interpret what has been expressed and therefore an interpretivist, epistemological stance was chosen consistent with a qualitative approach. This study aimed for an ethnographical approach, exploring the participants' experiences and seeking to understand perceptions and thus a phenomenological approach was taken. The open-ended interview was chosen for this study to gain a deeper understanding as within a more positivistic survey approach it may be more challenging for participants to fully express their experiences.

The analysis technique chosen for this study was a thematic approach. Braun and Clarke (2006) suggest that this method "works both to reflect reality and to unpick or unravel the surface of 'reality'" (p80). Cohen et al. (2011) compare Miles and Huberman (1994) Brenner et al. (1985) with the various strategies on coding, varying from 12 to 15 stages. They also cite Hycner (1985) who specifically produced advice on analysing phenomenological studies and it was through this article data analysis was influenced. Werner's orthographic principle (1957) was also considered whereby ideas that seem totally disconnected and disorganised slowly become clustered and links become more evident and understanding becomes clearer. Whilst this principle is related to child psychological development, it has relevance in this study since the aim of the data analysis was to sift, sort and allow links and relationships to emerge.

**Phenomenological interviewing approach**
Phenomenology is a description of a participant's experiences without bias and can be seen as a philosophical exercise (Silverman, 2013, p.99) and a precursor to future research investigations. Having been influenced by Bell's (2016) interviews with secondary teachers, this study also could not take a holist commitment to the methodology but used aspects of the phenomenological approach. Whilst interviewer bias was considered throughout and open ended questions and minimal interviewer contributions were phenomenologically sound, there was a structure throughout the interview which focused upon critical thinking and thus it became a semi-structured interview. Interviewees were firstly asked about D&T activities they had completed with their classes before being questioned about their thoughts on challenges and benefits of the subject in primary schools, completing a 'Jamboard' activity and finally being asked about critical thinking. Whilst a myriad of interesting themes transpired through the interviews, this paper relates solely to teacher perceptions of critical thinking.

**Jamboard activity**
Participants accessed a 'Jamboard', an online interactive whiteboard, and were asked to move 'sticky notes' into a hierarchal order. Hendley and Lyle (1996) completed a study asking pupils about the different learning attributes from D&T activities and this study used the majority of these for the sticky notes. Four notes were kept blank in case interviewees wanted to contribute their own ideas; but none of them did.

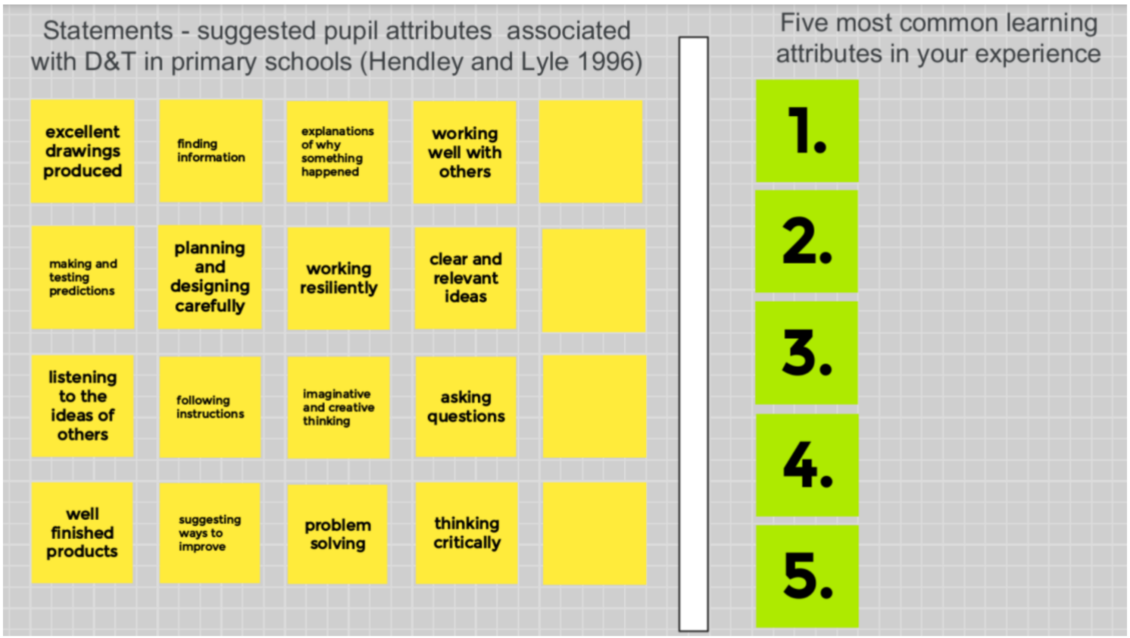



***Figure 1: Jamboard example***

**NVivo word cloud tool**
Whilst following a qualitative, phenomenology approach, quantitative methods were additionally used to analyse the transcripts as this can still aid the triangulation of thoughts within a phenomenographic study (Silverman, 2013). Using an online qualitative analysis tool (NVivo), word cloud diagrams were produced for every participant's transcript to enable an overview of key words and phrases. It must be said that any interviewer comments were

removed before this analysis in order to ensure the analysis was of the interviewee not the interviewer.

**Participants**

The study had eight participants gathered from social media, contacts within schools and, as can be seen from (Table 1), the majority of those who completed the interview were very experienced. I will declare here that I did know some of the interviewees but had last worked with them at least seven years prior to the interviews.

***Table 1: Overview of participant experience***

| Which of these best describes you? | Are you the D&T coordinator (or equ |
|---|---|
| **Participants who expressed interest and completed the interview** | |
| 10 years+ experience | No |
| 10 years+ experience | No |
| 10 years+ experience | No |
| 10 years+ experience | No |
| 6 years + experience | No |
| 6 years + experience | Yes |
| 2 years+ experience | No |
| Early Careers Teacher | No |

Whilst having a breadth of experience was positive, having participants from around the country provided an even wider experience. This could be seen as both a positive and a negative. The benefits meant a wide range of opinions from a large cross section of the country where training and expertise might be different but conversely it might be more challenging to explain why certain beliefs and perceptions have been expressed. With a phenomenological approach however, the emphasis is upon exploring and identifying themes and raising further questions rather than reasoning why something happens.

**Ethical Considerations**

A section on ethics can be “extensive, and they [ethics] are reflected through the research process” (Creswell and Creswell, 2018, p.90). Before implementation, the study was approved, via an ethics form, by the Faculty of Education and followed the guidelines set out by the British Educational Research Association (BERA, 2018). Assuring the safety of the participants through core principles of anonymity, confidentiality, informed consent and the freedom to withdraw were at the forefront of any decisions throughout the process. A risk assessment was completed thereafter to ensure the safety of all stakeholders was given due consideration.

At the initial expression of interest stage, informed consent and knowledge that any views would be kept anonymous and confidential was clear. This was supported later with a letter further explaining the interview process with the aim to put participants at ease and ask for their consent to continue – these letters were emailed back to me. Finally, at the beginning and end of every interview the interviewee was asked whether they wish to continue or have their views still taken. At every point, participants could withdraw their support.

Within all stages, it was made clear to participants the expectations and the purpose of study. As I would use quotes and information from the interviews to illustrate findings in the study, I could not promise confidentiality, therefore I had to ensure anonymity. However, as the participants came from a wide range of backgrounds and from schools throughout the country, I was confident of ensuring anonymity for individual participants by using pseudonyms and by making sure that the contextual information provided about each participant didn't make them identifiable. I also safeguarded that in every transcript, any mention of the school or location was removed.

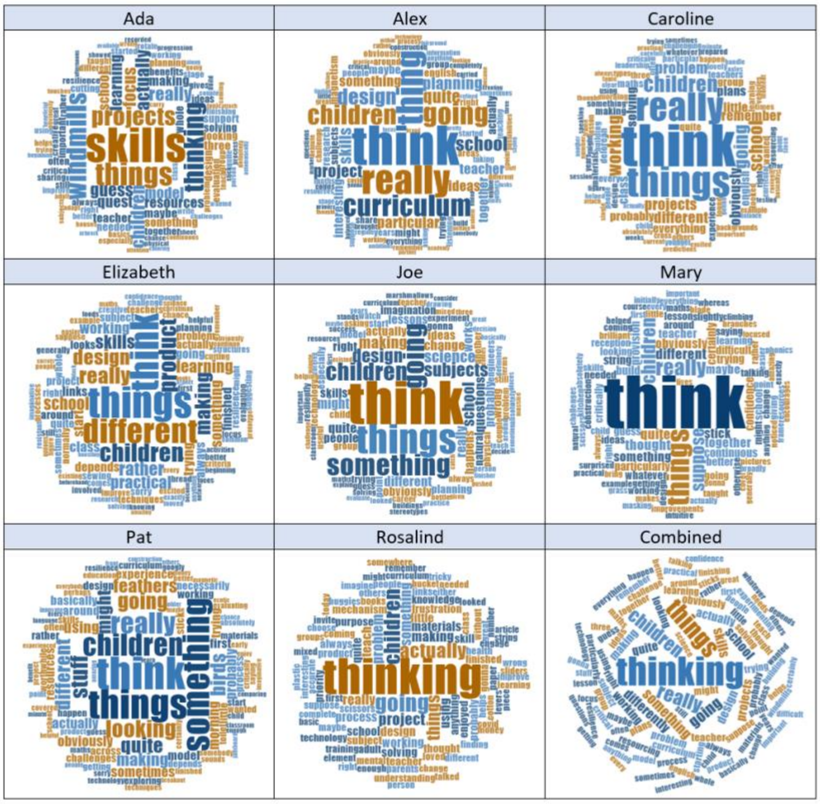
The key role was to "operate within an ethic of respect for any persons – including themselves – involved in or touched by the research they are undertaking." (BERA, 2018, p.6). The researcher is obligated to ensure all their participants are 'safe' and that the methodology is ethically considered throughout the research design and implementation process. It is through the interview design that most of the ethical considerations were measured but every decision was made in accordance with the BERA (2018) guidelines.

## Results

### Word cloud analysis

Looking at the Combined word cloud, 'thinking' was the key word to come from the transcripts which could possibly be explained by the fact that critical thinking are key words within the study. Whilst one also has to remember that responses in an interview might be 'I think that...', to have the word 'thinking' with the additional suffix implies that an action, product or process is occurring and this pattern emerged throughout each participant's interview. Although not as prominent within Ada's word cloud, 'thinking' is still one of the more commonly used words within the transcript and comes up as a high percentage within every other transcript. Key words of 'design', 'skills' and 'different' also have regular appearances and were considered throughout the thematic analysis.

***Table 3: Word cloud analysis***



## Hierarchal activity analysis

The below table 1.4 shows the outcomes of the Jamboard activity. Learning items placed as most commonly seen by teachers received 5 points, second most commonly seen learning received 4 and so on. *Working resiliently* and *problem solving* were clearly elements of learning teachers considered as beneficial from high quality D&T activities. Interestingly, *well finished products* and *excellent drawings* were not mentioned at all. *Critical thinking* was specifically mentioned by three out of eight interviewees (see Mode column representing how often each area of learning was chosen) but usually lower down in the hierarchy. The question this study suggests is whether skills such as problem solving for example, is in fact a key part of critical thinking itself.

***Table 4: Jamboard analysis; in order of frequency***

| Areas of Learning (from Hendley and Lyle (1993)) | Ada | Alex | Caroline | Elizabeth | Joe | Mary | Pat | Rosalind | Total | Mode |
|---|---|---|---|---|---|---|---|---|---|---|
| Working resiliently | 3 | | | 5 | 3 | 4 | 5 | 3 | 23 | 6 |
| Problem solving | 1 | 1 | 1 | 3 | 1 | 2 | 4 | 4 | 17 | 8 |
| Imaginative and creative thinking | 2 | | 5 | 4 | 4 | | | | 15 | 4 |
| Asking questions | | 2 | 4 | | 2 | | 2 | | 10 | 4 |
| Listening to the ideas of others | 4 | 3 | | | | 3 | | | 10 | 3 |
| Working well with others | 5 | | | | | 5 | | | 10 | 2 |
| Making and testing predictions | | | 2 | | | | 3 | 2 | 7 | 3 |
| Thinking critically | | | | | | 1 | 1 | 5 | 7 | 3 |
| Explanations of why something happened | | | | 1 | 5 | | | | 6 | 2 |
| Finding information | | 5 | | | | | | | 5 | 1 |
| Planning and designing carefully | | 4 | | | | | | | 4 | 1 |
| Suggesting ways to improve | | | | 2 | | | | 1 | 3 | 2 |
| Following instructions | | | 3 | | | | | | 3 | 1 |
| Clear and relevant ideas | | | | | | | | | 0 | 0 |
| Excellent drawings produced | | | | | | | | | 0 | 0 |
| Well finished products | | | | | | | | | 0 | 0 |

## Thematic analysis

Through analysis of the transcripts, three key themes of outcomes, approaches and attitudes emerged. A number of 'units of meaning' associated with each of these was recorded, quantified and transferred into a spreadsheet to demonstrate the results (Table 5). The blue coloured boxes denote the most mentioned theme within each interview, orange boxes denoting the least frequency. As can be seen, critical thinking was the most commonly mentioned emerging theme but it must also be stated that there was a question specifically about this within the interview.

*Table 5 Overview of themes from NVivo; in order of frequency*

| Thematic analysis | Emerging theme | Ada | Alex | Caroline | Elizabeth | Joe | Mary | Pat | Rosalind | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| *Outcomes* | *Critical thinking* | 11 | 8 | 10 | 5 | 7 | 11 | 8 | 4 | 64 |
| *Approaches* | *Creative and cross curricular* | 11 | 6 | 8 | 8 | 4 | 5 | 9 | 8 | 59 |
| *Attitudes* | *Teacher attitudes* | 3 | 10 | 7 | 6 | 4 | 10 | 3 | 8 | 51 |
| *Attitudes* | *Leadership and priorities* | 6 | 9 | 10 | 2 | 6 | 4 | 6 | 6 | 49 |
| *Approaches* | *Resource driven approaches* | 6 | 4 | 6 | 6 | 2 | 2 | 6 | 9 | 41 |
| *Outcomes* | *Resilience and problem solving* | 7 | 2 | 7 | 3 | 4 | 2 | 7 | 8 | 40 |
| *Attitudes* | *Pupil enthusiasm* | 4 | 3 | 3 | 6 | 4 | 6 | 3 | 10 | 39 |
| *Approaches* | *Collaboration* | 5 | 4 | 4 | 3 | 4 | 10 | 2 | 5 | 37 |
| *Outcomes* | *Inclusive* | 8 | 2 | 4 | 3 | 7 | 7 | 3 | 2 | 36 |

**Interview analysis of teacher perceptions**

One criticism of phenomenography is the challenge for the researcher to eliminate their preconceived ideas and focus on themes and patterns analysed from the transcripts (Webb, 1997). In addition, "different people may experience the same 'thing' in different ways." (Bell, 2016) and a researcher would need to be aware of the differing opinions upon the same subjects. However, by continually being aware of researcher bias the analysis retained an interpretive stance and became demonstrative of a "reflexive, reactive interaction between the researcher and the decontextualised data that are already interpretations of a social encounter" (Cohen et al., 2011). Throughout the process, being consistent of taking a phenomenological stance was maintained.

When analysing the transcripts, examples of critical thinking were evident within the interviews, albeit not always explicitly and defining critical thinking was occasionally an area some respondents asked for clarification. The Cambridge University Press (CUP) definition of critical thinking was shared to stimulate discussion where necessary and teachers were able to openly talk about their experiences. The three key areas of 'critical evaluation', 'analytical framework' and 'synthesising ideas' became themes arising from within the interviews and teachers reflected upon occasions that they had examples of critical thinking within the classroom. Considering that critical thinking was described by interviewees but not always recognised as such is an interesting example of the perceptions of the teachers about critical thinking within D&T activities.

**Critical thinking in D&T activities**

Within discussion about D&T projects teachers had taught, elements of all three categories of critical thinking were apparent. Examples of critical evaluation provided by the interviewees included making predictions about the products they were making and the consequences of potential design choices. Whether this be through the design process which many teachers were able to clearly communicate, or through trial and error, the teachers were able to identify children who had the "skills to be able to explain what they were doing, and what would what they thought would work better." (Ada).

Analytical framework examples included a range of problem-solving techniques. From children identifying problems and then reasoning solutions, to how children described and justified choices within their given project. To be able to differentiate between critical thinking and problem solving, Caroline suggested that “problem solving, to me is kind of the basis form of critical thinking, you've got problem solving where you solve a problem … whereas critical thinking is more, you're kind of anticipating problems as they come up”.

The final sub theme from the CUP (2019) of synthesising ideas can be defined as solving problems collaboratively or using ideas and information from different sources to create a structured plan. Ada described this as an “understanding is how to get from A to B and use all these bits and pieces in between.”

**Critical thinking and pupil outcomes**

The relevance of critical thinking within D&T tasks as a development of pupil outcomes is one that was mentioned favourably by the interviewees. Whilst Rosalind’s view was “I don't think much about thinking critically...well, just that I haven't thought about it myself much”, Alex was more forthright in the opinion that “D&T activities lend themselves perfectly to critical thinking” because they “lend themselves more than other tasks to being critically analysed”.

When discussing which children Ada felt demonstrated critical thinking skills, she gave the example where children look at their designs and “think critically about it and what they could improve, I guess, yeah, there's some children that it comes automatically.” Mary agrees with this whilst surmising that children “must think more critically than I had ever sort of given them credit for”. However, interviewees recognised the fact that not all children will naturally have this instinct, or perhaps even have had the prior experience, and this is key to planning future teaching opportunities.

**Teaching critical thinking**

Pat provided an example of a teaching technique to develop critical thinking skills within an Early Years environment for 3 to 5 year olds: “we sometimes teach explicitly, not criticizing each other's work necessarily, but perhaps we'll look at maybe a piece of art or something, and we'll talk about what we like about it”. Modelling skills to enable them to develop critical thinking skills is something that Ada also suggests as important and that she would “deliberately make a mistake and model those critical thinking skills so that would be beneficial to them.”

## Discussion

Critical thinking was evident throughout the interviews and during the analysis of attitudes towards D&T activities examples of critical thinking emerged consistently, consciously or subconsciously, even before the subject of critical thinking arose. One could suggest the importance of critical thinking within D&T activities is supported not only with the interviewee findings but also the research by Nicholl (2017), Spuzic et al. (2016) and Wei (2020) and teachers perceived skills needing critical thinking as attributes that appear within D&T activities.

Whilst nine themes emerged from the wider study analysis, elements of critical thinking were evident within many of them. Initially, some teachers needed further explanation of what critical thinking meant within a D&T context and Ab Kadir (2018) suggests that teacher subject knowledge of critical thinking is necessary in order to be promoted within classrooms. All respondents in this study gave examples of critical thinking before critical thinking was first mentioned which led me to conclude that critical thinking skills do exist within D&T activities but teachers do not necessary perceive them consciously.

The majority of research usually pertains to pupils older than the primary phase and thus the findings of this study could validate further investigation. It was also necessary to be pragmatic about how much could be achieved phenomenologically. The key themes emerging relating to critical thinking from the interviews provides justification and evidence to support future research within this age range. This could require a different research methodology. The aim of phenomenology is to gather themes and create further questions. These potential research avenues transpired through a phenomenological research stance and perhaps, for example, an action research project to gather evidence in practice through a series of observations and lesson studies may support the theories suggested from the respondents within this study and triangulate the evidence to support the notion that critical thinking is a valuable part of D&T activities.

This research has enabled me to reflect upon my own practice and consider how to utilise my understanding of teacher perceptions within the training I deliver for trainee teachers at the University of Cambridge and also within my school D&T activities as a D&T leader. The critical thinking skills and using D&T as a conduit to provide children with skills for their future materialised as important values from these interviews. The positivity from teachers within these interviews about D&T was also very pleasing.

## Final thoughts

To complete further research to evidence the existence, and importance, of critical thinking within primary school D&T activities is one that I personally feel has value for us to deliver high quality activities so that pupils have the skills to make "an essential contribution to the creativity, culture, wealth and well-being of the nation" (DfE 2013). The impact described above has made my research feel validated and that the area of critical thinking within D&T is an area worth researching. Though this may be a small-scale study, I hope that it has highlighted some key areas that could be addressed by the teaching profession to deliver high quality design education that would fulfil the wishes of industry to produce critical thinkers who can generate creative ideas and can collaborate in their problem solving.

## References

Ab Kadir, M. A. (2018). An inquiry into critical thinking in the Australian curriculum: Examining its conceptual understandings and their implications on developing critical thinking as a "general capability" on teachers' practice and knowledge. *Asia Pacific Journal of Education*, *38*(4), 533–549. https://doi.org/10.1080/02188791.2018.1535424

Barnett, R. (1997). *Higher education: A critical business*. McGraw-Hill Education (UK).

Bell, D. (2016). The reality of STEM education, design and technology teachers' perceptions: A phenomenographic study. *International Journal of Technology and Design Education*, *26*(1), 61–79. https://doi.org/10.1007/s10798-015-9300-9

Bell, D., Wooff, D., McLain, M., & Morrison-Love, D. (2017). Analysing design and technology as an educational construct: An investigation into its curriculum position and pedagogical identity. *The Curriculum Journal*, *28*(4), 539–558. https://doi.org/10.1080/09585176.2017.1286995

Bensley, D., Rainey, C., Murtagh, M., Flinn, J., Maschiocchi, C., Bernhardt, P., & Kuehne, S. (2016). Closing the assessment loop on critical thinking: The challenges of multidimensional testing and low test-taking motivation. *Thinking Skills and Creativity, 21*, 158-168.

BERA (2018) Ethical Guidelines for Educational Research, fourth edition https://www.bera.ac.uk/publication/ethical-guidelines-for-educational-research-2018-online

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77-101.

British Educational Research Association [BERA] (2018) Ethical Guidelines for Educational Research, fourth edition, London. https://www.bera.ac.uk/researchers-resources/publications/ethicalguidelines-for-educational-research-2018

Cáceres, M., Nussbaum, M., & Ortiz, J. (2020). Integrating critical thinking into the classroom: A teacher's perspective. *Thinking Skills and Creativity*, *37*, 100674. https://doi.org/10.1016/j.tsc.2020.100674

Cambridge University Press. (2019) *The Cambridge Life Competencies Framework: Critical thinking.* CUP https://issuu.com/cambridgeupelt/docs/cambridgelifecompetencies_criticalt_52e0186bc90c6c

Chew, S. W., Huang, X.-Y., Hsu, F.-H., & Chen, N.-S. (2020). Enhancing Critical Thinking Skills of Elementary School Students through Collaborative Learning. *2020 IEEE 20th International Conference on Advanced Learning Technologies (ICALT)*, 249–253. https://doi.org/10.1109/ICALT49669.2020.00082

Cohen, L., Manion, L., & Morrison, K. (2011). *Research methods in education* (7th ed). Routledge.

Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (Fifth edition). SAGE.

DfE (Department for Education) (2013). *The national curriculum in England: Design and Technology*. Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/239041/PRIMARY_national_curriculum_-_Design_and_technology.pdf

DfE (2016) Report of the Independent Panel on Technical Education. Retrieved from https://www.gatsby.org.uk/uploads/education/reports/pdf/report-of-the-independent-panel-on-technical-education.pdf

Dweck, C. S. (2012). *Mindset: Changing the way you think to fulfil your potential*.

Dyson, J (2005) Ingenia interview. Retrieved from https://www.ingenia.org.uk/Ingenia/Articles/c4125c9b-6e7d-4212-93ca-3fe81d6bf36b

Ennis, R.H. (2018) Critical Thinking Across the Curriculum: A Vision *Topoi* 37.1 (2018): 165-84. Web.

Erikson, M. G., & Erikson, M. (2019). Learning outcomes and critical thinking – good intentions in conflict. *Studies in Higher Education*, *44*(12), 2293–2303. https://doi.org/10.1080/03075079.2018.1486813

Facione, P. A. (1990). Critical Thinking: What It Is and Why It Counts. *Critical Thinking*, 31.

Facione, P. A. (2000). The Disposition Toward Critical Thinking: Its Character, Measurement, and Relationship to Critical Thinking Skill. *Informal Logic*, *20*(1). https://doi.org/10.22329/il.v20i1.2254

Gelerstein, D., Río, R. del, Nussbaum, M., Chiuminatto, P., & López, X. (2016). Designing and implementing a test for measuring critical thinking in primary school. *Thinking Skills and Creativity*, *20*, 40–49. https://doi.org/10.1016/j.tsc.2016.02.002

Halpern, D. F., & Riggio, H. R. (2002). *Thinking critically about critical thinking : A workbook to accompany Halpern's thought and knowledge*. ProQuest eBook Central https://ebookcentral.proquest.com

Hardy, A & Gomersall, S. (2017) Learning from each other: building relationships between primary and secondary D&T. *D&T Practice*, 1, pp. 32-34.

Hendley, D., & Lyle, S. (1996). Pupils' Perceptions of Design and Technology: A case-study of pupils in South Wales. *Research in Science & Technological Education*, *14*(2), 141–151. https://doi.org/10.1080/0263514960140202

Hennessy, S., & Murphy, P. (1999). The Potential for Collaborative Problem Solving in Design and Technology. *International Journal of Technology and Design Education*, *9*(1), 1–36. https://doi.org/10.1023/A:1008855526312

Hycner, R. H. (1985) Some Guidelines for the Phenomenological Analysis of Interview Data *Human Studies 8.*3 (1985): 279-303. Web.

Jagannathan, S., Ra, S., & Maclean, R. (2019). Dominant recent trends impacting on jobs and labor markets—An Overview. *International Journal of Training Research*, *17*(sup1), 1–11. https://doi.org/10.1080/14480220.2019.1641292

Kimbell, R. (2008). When it is and when it isn't. *Design And Technology Education: An International Journal, 13*(2). Retrieved from https://ojs.lboro.ac.uk/DATE/article/view/Journal_13.2_REF

Kimbell, R. (2017). Decisions by Design. *Design And Technology Education: An International Journal, 22*(2), 5-7. Retrieved from https://ojs.lboro.ac.uk/DATE/article/view/2263

Lai, E. R. (2011). Critical thinking: A literature review. *Pearson's Research Reports*, *6*(1), 40-41.

Mulnix, J. W. (2012). Thinking Critically about Critical Thinking. *Educational Philosophy and Theory*, *44*(5), 464–479. https://doi.org/10.1111/j.1469-5812.2010.00673.x

Newton, D. (2005). *Teaching design and technology 3-11*. Paul Chapman.

Nicholl, B. (2017). Empathy as an aspect of critical thought and action in design and technology education. In J. Williams & K. Stables, (Eds.), *Critique in Design and Technology Education* (pp. 157-171). Springer.

Rauscher, W., & Badenhorst, H. (2021). Thinking critically about critical thinking dispositions in technology education. *International Journal of Technology and Design Education*, *31*(3), 465–488. https://doi.org/10.1007/s10798-020-09564-3

Silverman, D. (2013). *Doing qualitative research* (Fourth edition). SAGE Publications Ltd.

Spuzic, S., Narayanan, R., Abhary, K., Adriansen, H. K., Pignata, S., Uzunovic, F., & Guang, X. (2016). The synergy of creativity and critical thinking in engineering design: The role of interdisciplinary augmentation and the fine arts. *Technology in Society*, *45*, 1–7. https://doi.org/10.1016/j.techsoc.2015.11.005

Stables, Kay. 2012. Designerly well-being: Can mainstream schooling offer a curriculum that provides a foundation for developing the lifelong design and technological capability of individuals and societies? Paper read at Technology Education in the 21st Century, at KTH, Stockholm.

Stupple, E. J. N., Maratos, F. A., Elander, J., Hunt, T. E., Cheung, K. Y. F., & Aubeeluck, A. V. (2017). Development of the Critical Thinking Toolkit (CriTT): A measure of student attitudes and beliefs about critical thinking. *Thinking Skills and Creativity*, *23*, 91–100. https://doi.org/10.1016/j.tsc.2016.11.007

Trilling and Fadel (2009) *21st century skills: Learning for life in our times* https://psycnet.apa.org/record/2009-18745-000

Vincent-Lancrin, S., González-Sancho, C., Bouckaert, M., de Luca, F., Fernández-Barrerra, M., Jacotin, G., Urgel, J., & Vidal, Q. (2019). *Fostering Students' Creativity and Critical Thinking: What it Means in School*. OECD. https://doi.org/10.1787/62212c37-en

Wei Leong Leon LOH, (2020) Critical Thinking in Problem Exploration in Design and Technology Design Project. *Design and Technology Education: An International Journal, 25(1)* 35-54

Werner, H. (1957). *Comparative psychology of mental development*. New York: International Universities Press.

Willingham, D.T. (2020) Ask the Cognitive Scientist: How Can Educators Teach Critical Thinking?" American Educator 44.3: 41. Web.

Yang, S. C., & Chung, T.-Y. (2009). Experimental study of teaching critical thinking in civic education in Taiwanese junior high school. *British Journal of Educational Psychology*, *79*(1), 29–55. https://doi.org/10.1348/000709907X238771

# Weaving the specialist material strands of design and technology together

**Sarah Davies, Nottingham Trent University, UK**

## Abstract
The design and technology curriculum in England has gone through various policy changes since its introduction in the Education Reform Act of 1988. The 2014 policy revised the content to make it slimmer and outlining the essential core knowledge for Key Stage 1 to 3. Schools need to consider wider aspects of design and technology not included in the National Curriculum which they would like to teach as part of their own school curriculum (DATA n.d.). Previous research into D&T explored the challenges of adapting established ways of working and the issues involved in sub-cultural retreat by teachers. This research paper sets out to understand how teachers coped with the 2014 curriculum change and the factors influencing teachers' capacity to implement assessment changes that impacted the need to teach more broadly. The larger investigation followed a qualitative methodology and collected interview data during the first round of teaching the new upper-secondary examination courses in English secondary schools. An interpretive approach to the analysis suggests two ways the teachers conceptualised the change as "coming off the circus of specialist rotations" and "teaching inside a specialism". Challenges for the teachers included the issue of specialist knowledge, traditions of curriculum organisation, opportunities to share expertise, and attitudes towards the policy shift. Teaching outside a specialism is a way to think about supporting pre-service and in-service teachers with the current policy change and ways to modernise the subject in school.

## Keywords
Policy change, Design and Technology teachers, Established teaching methods, Teaching in and outside a specialism, D&T Programmes of Study

## Introduction
Design and technology teaching has traditionally developed within schools to cover a range of short projects taught by individual specialist teachers that provide expert teaching in one (or two) material areas, comprising electronics, food, graphics, resistant materials (RM), textiles, or systems and control (S&C). During initial teacher education (ITE), design and technology teachers typically specialise in one or two material areas related to their first degree (Design and Technology Association, 2010). This pattern of teaching and training was challenged in 2014, through a new Key Stage Three (KS3) curriculum, which introduced a single design and technology examination (DfE, 2013; DfE, 2015) and a Subject Knowledge Enhancement Course (SKE) to support pre-ITE training (DfE, 2021).

Whilst the timescale of the policy change did not affect examination teaching until 2016, secondary teachers faced an unprecedented challenge to their established practice (Davies, 2022). The discontinuation of all but one specialist pathway (Food Nutrition and Preparation) and the shift to a single design and technology examination in upper-secondary – Key Stage Four (KS4) - led to a steep learning curve and disruption of curriculum plans for teachers working in English design and technology departments. Teachers needed to move away from their traditional teaching practice within specialist material areas and embrace a combined way of teaching and thinking about the subject. Not an easy task, due to a climate where most schools continued to advertise for new teachers with a specialism, and whilst in post, teachers take on the role of an expert within that material strand.

Currently, lower-secondary curriculum - KS3 - is typically organised into four to six project rotations that develop pupils' knowledge and skills associated with a specialism. Within the traditional context, technical and process skills are developed through design and make activities that focus on one material area. Specialist workshops and classrooms provide the environment for each teacher to deliver their bespoke specialist design and make projects which are timetabled to repeat through the year with different groups of pupils. The policy change to a single General Certificate of Education (GCSE) for design and technology disrupts the established practice of project rotations and the view that design and technology knowledge should be taught through material specialisms (Ashbee, 2021). As design and technology departments attempt to move forward and change, the issue of shifting teachers' established practice from material expert to design and technology generalist requires special attention and planning. Teachers with experience of delivering design and technology through a rotation model know that effective policy developments depend on their capacity to adapt to the changes. The following study is placed at the mid-point of the educational change. It focuses on the stories of two teachers to provide insights into how these different teachers started to question and adapt established practices in response to the change.

## Literature Review

Changes to the design and technology examination and National Curriculum (NC) arose from a review instigated by a change in government. A desire to compete internationally with high-performing countries led to a review of perceived weaknesses with the previous curriculum iteration, and recommendations to revise curriculum policy to focus on essential knowledge within key subject disciplines (DfE, 2010). The review led to a new policy for design and technology that emphasised technical knowledge and contextual understanding over practical knowledge and skills (DfE, 2013; DfE, 2015). The move to teaching through contexts rather than material specialism, for example textiles, shifted the nature of curriculum design within the subject. Fullan (2015) highlighted the implication of policy change that reduced or removed aspects of curriculum that teachers valued when he recommended the importance of alignment. More recently Van Deventer & Steyn's (2022) research into design teachers' attitudes towards a modified curriculum in South Africa claimed that clear identification of problems associated with change supported implementation success. In addition, the research observed the way teachers were likely to disengage with the process of change if not consulted from the outset. However, the scope of this work remains focused on understanding the English context and the specific challenges that teachers encountered during the phase of policy change that impacted KS4 assessments and the move away from specialisms at KS3.

In the English secondary school, it is typical to witness design and technology lessons organised through a rotation system (also called a circus or carousel) despite pedagogical criticism (McGimpsey, 2011; Miller & McGimpsey, 2011). A rotation system characteristically involves KS3 pupils moving from one material specialism and specialist teacher to another, generally four to six times a year. The system was initially set up in the 1990s to accommodate the new NC subject, combining the study of Home Economics and Craft Design and Technology (CDT).

Rotation systems allowed each teacher time to deliver subject content in specialist teaching spaces (Penfold, 1988). However, the cyclical nature of teaching through a rotation promotes a narrow focus on each material specialism and the potential for the repetition of general design principles (Hardy, 2020). Therefore, department teachers need to share information about their pupil's attainment to support the transition from one teacher to another so that each teacher can build upon the pupil's strengths and areas for development (Pollard et al., 2019). Something that findings from Ofsted (2008; 2011) identified as the best way to ensure design and technology rotations are successful.

Design and technology teachers are generally trained to teach one to two specialisms within the subject unless trained through a pre-training SKE course. The nature of design and technology teacher education separates specialist knowledge and experiences and prepares student teachers to take up specialist roles. Specialist roles that, according to Bell (2015) encompass Computer Aided Manufacture (CAM), Computer Aided Design (CAD), Technological Textiles, S&C, Engineering, Electronics, Food Technology, RM, Product Design (PD), Apparel Textiles and Graphic Design. Early research into the policy implementation identified a lack of alignment between teachers' practice and the policy's aim to combine specialist material areas into a single design and technology examination (Choulerton, 2016). Within this research, design and technology teaching continued the notion of specialist pathways associated with the old General Certificate of Education (GCSE) across KS3, and teachers appeared to not engage with the shared forms of knowledge and general design principles that the new policy advocated. Shared forms of knowledge are defined by Reinsfield & Williams (2018) as technological knowledge that is general to all aspects of the subject and different from technical knowledge that is specialist.

**Teacher agency and Boundary crossing**

In addition to showing the challenges teachers faced when adapting established practices in response to the policy change, this research sought to identify past activities that influenced intentional actions in the present. Teacher agency has been used to theorise the shift to teaching more broadly and shed light on the factors that support a change in practice. The theory of teacher agency defines teachers’ actions as intentional and socially dependent because what teachers' do and who they do it with, shapes and is shaped by the social context within which the actions occur (Priestley et al., 2013; Scott, 2007). Teachers' capacity to purposely adapt their practice to align with the new policy is, therefore, time related and informed by the social world of policy documents, departmental ideas, and teaching habits (Emirbayer & Mische, 1998, Hardy & Davies, 2021).

The previous idea of specialist examination pathways and specialist material area KS3 projects created the social habit of separating aspects of design and technology into discrete mini subjects. Separate aspects of the subject with their boundaries of unique min subject knowledge, pedagogy, and ideas. Subject boundaries encapsulate how teachers practice and make sense of a subject (Goodson, 2013) - informing the shape of teachers' work and influencing the activities teachers take within their role. In this case, they identify with a material area specialism and define their role within a subject department as a specialist (Britzman, 1992). The shift to teaching more broadly requires teachers’ future action to focus on the intentional crossing over into other subject boundaries. When this was historically required of home economics and CDT teachers at the start of NC design and technology, research from Paechter's (1995) identified the practice of sub-cultural retreat where some teachers chose to withdraw from the subject.

## Research Design

This research aimed to generate knowledge about the qualitatively different ways teachers, who completed their ITE with one university provider, responded to and implemented the subject policy changes introduced in 2014. In addition, the research investigated the factors influencing design and technology teachers' capacity to implement change. The overarching question to be considered was:

- In what qualitatively different ways have design and technology teachers translated policy development into practice?

A qualitative study explored 12 teachers' day-to-day experiences of subject change through in-depth interviews. A qualitative and interpretative methodology was chosen for this research because it allowed for collecting rich data in a natural setting (Robson & McCartan, 2016). Qualitative research allows for both inductive and deductive methods of interpretation that use theory to frame the research problem (Creswell & Poth, 2018). This approach supports the generation of data that includes descriptions and interpretations of the problem reported in ways that capture the voice of participants and contribute to ideas for change.

Aspects of the phenomenographic approach informed the strategy for exploring how teachers made sense of policy development (Barnard et al., 1999). Phenomenography is a qualitative research method built on the phenomenological approach to answering questions about a collective experience (Bowden, 2000; Marton, 1981; Marton, 1986; Trigwell, 2006). Although this approach does not usually promote the richness of individual experiences, Ashworth and Lucas (2000) argue for including rich individual descriptions that aim to conceptualise detailed accounts of the lifeworld of participants, leading to individual profiles that can be cross-referenced as part of the interpretative process.

Using in-depth interviews, allows for thick descriptions of research participants' experiences through a conversation between researcher and participant that offers maximum freedom (Creswell & Poth, 2018; Robson & McCartan, 2016; Silverman, 2015). Validity can be achieved in a range of ways, including collecting data within the participants' natural setting, researcher reflexivity, and participant transcription checking. As a qualitative phenomenographic methodology guides the study, the primary sources of data came from in-depth interviews with the secondary design and technology teachers during the academic year 2018 - 2019.

### Data Analysis

Data analysis followed a creative approach (Kara, 2015) where data was collected with supporting field notes and visual sketches, leading to a set of composite individual teacher descriptions (Ashworth & Lucas, 2000; Checkland & Poulter, 2006). Findings were recorded and coded, leading to researcher themes (Gibbs, 2018; Saldaña, 2013). The choice of a qualitative approach generated subjective knowledge and experiences that, although not universal, offered individual truths about insights into the problem. For ethical reasons, the participants' real names have not been used.

**The research context**
This paper will present the findings from two teachers in two secondary schools. The first teacher is Judith, a food and textile technology trained teacher, who had learnt to teach outside her specialism across two schools. In contrast, Mary had only taught textiles technology despite completing her training in all aspects of design and technology. In addition, she has been nationally recognised as an outstanding newcomer by the subject association for her work in curriculum development.

*Judith*
Judith was in her 11th year of teaching design and technology at her current secondary school and worked with a small team of supportive teachers. She had transferred her practice of what she described as "coming of the circus" to her current school, which had welcomed the chance to move away from the rotation model. Judith believed that pupils needed to experience all aspects of the subject, including the different material specialisms and that young people should develop solutions to real-world problems rather than only learning to make existing products. She explained that she felt this way because of her background in the fashion industry, where she saw that design was not just about making products but understanding technical data and ergonomics. So, she was enthusiastic about the aims of the new design and technology GCSE qualification. In Judith's school, KS3 was taught through four material-focused short projects and one multi-material end-of-year project in Years 7 and 8 (11 - 13 years). At KS4 pupils were grouped in relation to the specialist technical knowledge material option they chose. In turn, their choice led to additional specialist questions within the written aspects of the GCE examination, and Judith taught a textile focused group. Judith recognised that the shift to teaching an integrated KS3 curriculum would rely on the willingness of the department team to share expertise and respond to the challenge of teaching through contexts rather than short, mainly making projects.

*Mary*
Mary was in her third year of teaching textiles lessons within a creative arts department comprising art, design, and technology teachers. She worked in isolation on the planning, teaching, and assessment of KS3 textiles and a GCSE group made up of pupils that specialised in textiles. Mary talked about a lack of time or appetite for collaboration on planning despite her involvement in national courses that advocated a team approach to planning. Mary described how she networked with other enthusiastic colleagues outside her department through her involvement in a school-level assessment group. She had started to see her ideas trickle into the department's teaching but generally described a lone approach to teaching design and technology. Mary expressed an initial frustration when she started at the school that pupils achieved in the artistic side of drawing their design ideas, but they struggled to demonstrate a knowledge of the materials and processes involved in manufacturing their products. She believed pupils required this technical knowledge and adapted her teaching plans accordingly.

## Findings
Mary and Judith were enthusiastic about how teaching pupils for more extended periods in the academic year led to stronger pupil achievement and engagement with the subject. Mary claimed the move to teaching pupils for longer had a more substantial impact on pupils' progress than the previous iteration of the short six-week regime when she states:

> *Their knowledge and understanding of design and technology seem to be a lot better embedded than the year nine's when I started at the school (Mary).*

In Judith's school, the timetable allowed teachers to work with the same pupils over two years. She explained that:

> *To track the progress, we felt it helped to keep the kids for the year, and we even tried to keep them for two years. I've got one group who I have had since year seven who are now doing their options in year eight - everyone in my class is taking design and technology (Judith).*

Mary emphasised how each colleague in the department had a separate role from the other. She stated:

> *I'm the only person doing textiles. So, I've had full accountability for what I've written for the textiles scheme of work, and the food teacher has had full accountability for her [area], and the robotics and the RM staff have had the same for theirs (Mary).*

Both teachers emphasised the need to learn the new knowledge required to understand the new elements they needed to teach. Judith highlighted the practice at her school of prioritising departmental time for professional development. She stated:

> *We have two staff meetings a week - one on a Monday and then on a Wednesday. As a department, we knew, obviously, we wanted to be flexible and be trained in all these different areas, so we decided, right, we are going to use that Wednesday [to teach each other].*

In contrast, Mary focused on her experience of making decisions about how the lesson content would be shaped by the non-specialist teacher and the compromises she would make to ensure future lessons could be taught by all team members. She stated:

> *Sometimes I'll plan a really hands-on lesson, which has lots of like handling kits, tips, bits and pieces that I have in and around your classroom, and you can quite easily pull together. So, when I have planned these lessons, I can't do that, so, I've held back from doing perhaps more exciting lessons, because I've thought about resourcing and practising with them. I suppose the nature of the lesson you've got, to give to somebody else, you want to make it quite easy for them to pick up. So, something that you might not naturally do in your teaching style.*

Judith and Mary drew attention to the teaching spaces for design and technology. Highlighting the link between workshops, equipment, and making specialist products. Judith was enthused about the need to help pupils appreciate that workshops did not have to be associated with one specialism. She asserts that:

> *Even though we might be in the textiles room, we might be working on polymers, or we might be working on, you know, doing moulds for pewter casting. So, we've tried to break the kind of attitude from the kids really that just because they're in this room that they'll be doing this?*

Both Mary and Judith emphasised the need to teach the pupils about the breadth of the subject and not to focus on previous GCSE pathway strands. However, as Judith worked in a school that had already embraced the shift to teaching all aspects of design and technology, she talked less about issues associated with subject content. Whereas Mary enthused about the need to broaden the teaching of textiles from a vocational fashion viewpoint to a more general view of textile applications when she stated:

> *I didn't ever consider textiles as being part of the automotive industry or being part of medicine, or all the other wonderful things that it's part of in the world. In a much bigger spectrum than I perhaps understood when I was at school. So, I think it is quite important at that age to have that open… Yeah, to have that openness about it. Because I think I only ever understood it as "fashion and interior design". I didn't ever really think about the other places it could take you. I think that that's really important for children to understand.*

The experiences that emerged from these findings centred upon a teacher's understanding of what a transformed design and technology might look like and what they needed to do to achieve this. The research findings suggest that a teacher's approach to the planning and teaching of design and technology is influenced by their ideas about the subject and how lessons are organised in the school. The dimensions of " Coming off the circus of specialist rotation" and "Teaching inside a specialism" are a means to elaborate on factors that influence the teachers' capacity to implement change.

**Coming off the circus of specialist rotation**

"Coming off the circus of specialist rotation" was represented by Judith when she described the department's approach to organising teaching to ensure one teacher worked with the same group of pupils over the whole teaching year (DfE, 2013; DfE, 2015). In addition, she explained how the department judged the practice to support pupils' progress by allocating one teacher to one group and described how the decision had led to more robust engagement in the subject as more pupils chose to study the subject at a higher level. Mary represented the theme of "coming off the circus of specialist rotations" when she described her school's approach to extending the length of specialist projects, thereby reducing the number of rotations a pupil went through in one year (Ofsted, 2008; Ofsted, 2011). She reflected positively on her observations related to the shift to longer rotations when she described how the new practice led to higher progress and attainment for her learners as they engaged with essential knowledge in the discipline (DfE, 2010).

For Judith, the move to teaching all aspects of design and technology was influenced by her previous school experience and in matching her hopes for the subject to develop technological knowledge in pupils (Reinsfield & Williams, 2018). The shared knowledge and understanding of the subject that pupils could draw upon when engaged in learning through contexts, like the one multi-material end-of-year project delivered in Years 7 and 8. Both Judith and Mary represented the issues associated with "coming off the circus of specialist rotation" in relation to non-specialist teachers developing new knowledge and skills that were motivated by a need to adapt. They described how their colleagues needed to learn the specialist elements that were not their own specialisms, and vice versa. Judith described the move to using meeting time to undertake professional learning, whilst Mary described the production of resources that needed to be practiced with her non-specialist colleagues. For Mary, the role of sharing expert knowledge was focused on preparing simplified teaching resources that potentially limited the specialist content and pedagogical approaches that in Mary's view, only a specialist could deliver (Goodson, 2013).

Judith's idea that the textile classroom could be used for more than teaching textiles was motivated by her aspiration to change how the subject was perceived. For Mary, her experience of learning textiles at school was questioned when she described how she had started to recognise the breadth of the subject and ways to view textile teaching beyond a narrow focus. She could imagine a future for her learners that looked different to her own and offered broader pathways than the vocational aspirations of the previous policy iteration. The key here is that both Judith and Mary were starting to see how specialist knowledge might entwine with other specialisms to broaden the subject, colleagues' skills, and teaching environments.

### Teaching Inside a Specialism

The theme of "teaching inside a specialism" was reinforced by both Mary and Judith when they described the design of the single-subject GCSE into specialisms that mirrored the previous iteration of specialist examination courses and created textile groups (McGimpsey, 2011; Miller & McGimpsey, 2011). In Mary's school, this was repeated in KS3, and she articulated how this established a concentration of specialist knowledge and teaching rooms within her department (Penfold, 1988) as each teacher focused on a singular specialist material aspect of the curriculum (Bell, 2015). When describing the planned shift away from rotations Mary admitted apprehension about the capacity of her non-textile specialist colleagues to teach lessons in the way she would. Her textile specialist knowledge was not easy to "pick up" because she believed that teachers operating outside their subject boundary would struggle to make learning as engaging (Goodson, 2013). If departments choose to continue to adopt GCSE organisation that keeps the specialist strands apart, then it will be more challenging to break the established cycle of rotations at KS3. If teachers do not see inside each other's subject boundaries, they are more likely to retreat (Paechter, 1995) and miss opportunities to share the collective expert knowledge that makes design and technology a rich subject to study.

## Discussion

The current study found that these teachers either taught or planned to teach outside a specialism by designing the curriculum to allow teachers to work with the same pupils over one academic year. However, the two cases show that design and technology teachers continue to adopt a specialist role by planning the aspects of the curriculum that relate to the knowledge associated with each material strand. In addition, Judith describes meeting times within and after the school day to share expertise across the team. The use of in-house professional development limits the teachers' capacity to develop specialism expertise if that knowledge is missing from within the team or school. For example, a school that lacked a teacher with S&C expertise might remove that aspect from the curriculum. The shift to sharing expertise and teaching specialist content indicates that teachers are starting to teach more broadly (Choulerton, 2016). Teaching the full spectrum of what design and technology offers allows teachers to build on pupils' strengths and areas for development across the year rather than over a short unit of specialist material learning. However, the results do not show how teachers map the shared technological knowledge and general design principles across the specialist projects (Ashbee, 2021; Hardy, 2020; Reinsfield & Williams, 2018), or share information about pupil’s attainment (Pollard et al., 2019).

These results further support the idea from Emirbayer & Mische (1998), who identified how the social world of agents influences the actions they are prepared to take in the present. Mary and Judith observed the pupils in their social world struggling with an understanding, in Mary's case, and a desire to develop design and technology capability through weaving material specialisms together. This is consistent with Van Deventer & Steyn's (2022) observation that in problematising the situation, a change can be implemented successfully through intentional actions (Priestley et al., 2013; Scott, 2007). When Mary saw that her pupils were struggling with technical knowledge and wanted to pursue careers and futures beyond vocational pathways in design and technology, she questioned the subject's purpose and the divisions that specialist material areas offer, aligning her values with the curriculum change (Fullan, 2015). However, she also expressed fear about the watering down of her teaching materials confirming Goodson's (2013) idea that practices and ideas shape individual subjects' boundaries.

The implications for ITE are questions around how to support trainee students who do not experience departments that have opted to "come off the circus of specialist rotations". For example, if a trainee teacher's school training experience is limited to specialist projects, then they are less likely to understand and envisage a future curriculum that embraces the full range of design and technology, and a likely consequence is that they would see their role as limited to specialist teaching (Britzman, 1992). In addition, implications for school departments centre around how to utilise newer teachers who come into the profession that might come into a school with broader aspirations and expertise. The reluctance of Mary's department to work as a team and map the curriculum from a holistic viewpoint demonstrates the factors within a teacher’s school that separate subjects and create barriers despite the teachers past experiences of learning about the various specialisms during a pre-ITE training course (DfE, 2021).

Despite the results that show how these two teachers have moved the established teaching model from specialist rotations towards a coherent curriculum model that all design and technology teachers deliver, there are still questions about how to shift each projects content from specialist to shared knowledge that each department of teachers can agree on. In addition, it seems possible that these results were caused by the importance that GCSE examinations have within a school and how these create an imperative for teachers to adapt practice in relation to a policy reform. For those departments that have not yet moved to a shared delivery model at KS3 it is likely that they will not feel the need to question traditional rotation models until the next policy shift and alternations to GCSE examinations.

## Conclusion

The purpose of this paper was to understand how teachers coped with a recent policy change and to determine the factors influencing teachers' capacity to implement assessment changes related to the shift to a single design and technology examination. This research indicates that teachers manage a policy change by adapting established practices in ways that both support and conflict with traditional ideas about how to design curriculum delivery. It is evident that some teachers have the capacity to draw on past experiences and align the actions of “coming off the circus of specialist rotations” with their hopes for the subject, whilst others continue “teaching inside a specialism”, despite experiences during pre-service training. Such a response sems appears counter to developing a subject that has universal appeal and a role to play inn general education. The identification of these different approaches to practice within design and technology highlight the role of past experiences and departmental contexts in the quest to challenge the tradition of “teaching inside a specialism” and move towards a curriculum experience that reflects the modern intentions of the current English design and technology curriculum policy. The priority for future research is to find out if these teacher’s experiences are unique or representative on a wider scale across different ITE providers and geographical locations.

## References

Ashbee, R. (2021). Curriculum: Theory, Culture and the Subject Specialisms. Routledge.

Ashworth, P., & Lucas, U. (2000). Achieving Empathy and Engagement: A practical approach to the design, conduct and reporting of phenomenographic research. Studies in Higher Education, 25(3), 295-308. https://doi.org/10.1080/713696153

Barnard, A., McCosker, H., & Gerber, R. (1999). Phenomenography: a qualitative research approach for exploring understanding in health care. Qualitative Health Research, 9(2), 212-226.

Bell, D. (2015). Design and Technology; Educational fallacy or principal exponent of school-based STEM activity? Paper presented at the Annual Conference for Research in Education (ACRE), Research Poster.

Bowden, J. A. (2000). The nature of phenomenographic research. In J. Bowden, & E. Walsh (Eds.), Phenomenography (pp. 1-18). Royal Institute of Technology University Press.

Britzman, D. P. (1992). The terrible problem of knowing thyself: Toward a poststructural account of teacher identity. Journal of Curriculum Theorizing, 9(3), 23-46.

Checkland, P., & Poulter, J. (2006). Learning for action: a short definitive account of soft systems methodology and its use for practitioner, teachers, and students. Wiley.

Choulerton, D. (2016). Design and Technology Association summer school 2016 keynote speech. SlideShare. https://www.slideshare.net/Ofstednews/datasummerschoolkeynote2016

Creswell, J. W., & Poth, C. N. (2018). Qualitative Inquiry and Research Design: Choosing Among Five Approaches (4th ed.). Sage.

Davies, S. (2022) What are design and technology teachers doing in response to a subject change? EdD thesis, University of Nottingham.

DATA (no date) ‘Design and Technology National Curriculum for England 2014’, available from, https://www.designtechnology.org.uk/for-education/curriculum/dt-national-curriculum-for-england-2014/, [accessed 4th August 2023]

Department for Education. (2010). The importance of teaching: the school’s white paper. GOV.UK. Retrieved Jul 20, 2017, from https://www.gov.uk/government/publications/the-importance-of-teaching-the-schools-white-paper-2010

Department for Education. (2013). National curriculum in England: design and technology programmes of study. GOV.UK. Retrieved July 17, 2014, from https://www.gov.uk/

Department for Education. (2015). GCSE design and technology. GOV.UK. Retrieved September 09, 2016, from www.gov.uk/government/publications/gcse-design-and-technology

Department for Education. (2021). Subject knowledge enhancement: an introduction. GOV.UK. Retrieved Sep 14, 2021, from https://www.gov.uk/guidance/subject-knowledge-enhancement-an-introduction

Design and Technology Association. (2010). Minimum competences for trainees to teach design and technology in secondary schools (Revised edition ed.). Design and Technology Association.

Emirbayer, M., & Mische, A. (1998). What is agency? American Journal of Sociology, 103(4), 962-1023.

Fullan, M. (2015). The New Meaning of Educational Change. Japan: Teachers College Press.

Gibbs, G. R. (2018). Analysing qualitative data. Sage.

Goodson, I. F. (2013). School subjects and curriculum change. Taylor and Francis.

Hardy, A. (2020). Learning to Teach Design and Technology in the Secondary School: A Companion to School Experience (4th ed.). Routledge.

Hardy, A. & Davies, S., (2021). Implementing curriculum changes. In: A. Hardy and E. Norman, eds., Redesigning D&T ... thinking ... talking. Loughborough: Loughborough Design Press, p. 8. ISBN 9781909671263

Kara, H. (2015). Creative research methods in the social sciences: A practical guide. Policy Press.

Marton, F. (1981). Phenomenography—describing conceptions of the world around us. Instructional Science, 10(2), 177-200.

Marton, F. (1986). Phenomenography—a research approach to investigating different understandings of reality. Journal of Thought, XXX, 28-49.

McGimpsey, I. (2011). A Review of Literature on Design Education in the National Curriculum. London: RSA.

Miller, J., & McGimpsey, I. (2011). What's wrong with DT? The Royal Society of Arts. Retrieved Feb 27, 2018, from https://www.thersa.org/reports/whats-wrong-with-dt

Ofsted. (2008). Education for a technologically advanced nation. London: Ofsted. http://dera.ioe.ac.uk/8197/1/Education%20for%20a%20technologically%20advanced%20nation%20%28PDF%20format%29.pdf

Ofsted. (2011). Meeting Technological Challenges? Design and Technology in Schools 2007–10. (No. 100121). Manchester: Crown copyright. https://www.gov.uk/government/consultations/arrangements-for-non-exam-assessment-for-qualifications-in-2022

Paechter, C. (1995). Subcultural Retreat: negotiating the design and technology curriculum. British Educational Research Journal, 21(1), 75-87. 10.1080/0141192950210106

Penfold, J. (1988). Craft design and technology: Past, present and future. Trentham Books Limited.

Pollard, A., Black-Hawkins, K., Cliff-Hodges, G., Dudley, P., & James, M. (2019). Reflective teaching in schools: Evidence-informed professional practice (5th ed.). Bloomsbury Publishing.

Priestley, M., Biesta, G., & Robinson, S. (2013). Teachers as agents of change: Teacher agency and emerging models of curriculum. Reinventing the curriculum: New trends in curriculum policy and practice (pp. 187-206). Bloomsbury London.

Reinsfield, E., & Williams, P. J. (2018). New Zealand secondary technology teachers' perceptions: "technological" or "technical" thinking? International Journal of Technology and Design Education, 28(3), 739-751.

Robson, C., & McCartan, K. (2016). Real world research. John Wiley & Sons.

Saldaña, J. (2013). The coding manual for qualitative researchers (2nd ed.). Sage.

Scott, D. (2007). Critical essays on major curriculum theorists. Routledge.

Silverman, D. (2015). Interpreting qualitative data (5th ed.). Sage.

Trigwell, K. (2006). Phenomenography: An approach to research into geography education. Journal of Geography in Higher Education, 30(2), 367-372.

Van Deventer, A., & Steyn, R. (2022). Teachers' attitudes towards the amendments in the Design curriculum. Design and Technology Education: An International Journal, 27(2), 53-69.

Design and Technology Education: An International Journal

28.2

# Design and Technology Educators' Experiences of Competence, Relatedness and Autonomy with Educational Research

**Matt McLain, Liverpool John Moores University, UK**
**Daniela Schillaci-Rowland, Presdales School, UK**
**Kay Stables, Goldsmiths, University of London, UK**
**Alison Hardy, Nottingham Trent University, UK**

## Abstract

This article reports on the results of a survey of Design and Technology educators, predominantly based in England that sought evidence of the extent to which the educators engaged with educational research more generally and also specifically within Design and Technology Education. The survey was sponsored by the professional Association of Design and Technology Education and was undertaken by its Design and Technology Research Steering Group. The survey collected demographic data on the roles and responsibilities of the survey respondents, the types and levels of education where they worked and length of experience in Design and Technology education. Questions explored the types of research of interest, confidence levels in accessing, using and undertaking research, the nature of support for engaging research that educators would welcome, how research was currently accessed, what the challenges and barriers might be and what would motivate educators to become more engaged with research. This article resorts on analysis of the data, drawing on Self Determination Theory and specifically concepts of competence, relatedness and autonomy. Findings indicated that respondents had a great deal of interest in principle, but that there were considerable barriers to engaging with research which impacted on competence, relatedness and autonomy. The insights provided will now be used as the basis for developing support for Design and Technology practitioners to engage with research at a variety of levels.

## Keywords

Autonomy, Competence, Design & Technology, Relatedness, Research, Self Determination Theory

## Introduction

There has been growing interest in schools in England in educational research and evidence-informed practice in recent years. As with many changes in the national landscape, there is a policy drive behind this change, with the associated focus by schools on approaches that are overtly or subconsciously sanctioned by the power brokers, such as the Department for Education (DfE, 2017, 2013) the government department responsible for schools and curriculum, and the Office for Standards in Education (Ofsted, 2020) the inspectorate for schools in England. The current trend is for cognitive science and randomised controlled trial research, promoted by the Educational Endowment Fund (EEF, 2023; Impetus, 2023), established with a £125 million grant from the DfE in 2011 (Impetus, 2023). However, the jury is still out on the current fixation on research from the cognitive sciences, regarding its efficacy in real-world education practice – i.e., classrooms, workshops, labs, etc. – even from its proponents (Perry et al., 2021; Perry, 2022).

Irrespective of whether or not one agrees with the narrow focus promoted in schools in England, there are three key assumptions made by policy makers; first that teachers want and see the benefit to being more research informed, second that they have ready access to relevant and high-quality research findings, and third, that they are able to effectively engage with and apply research in their classrooms.

This study explored these assumptions, investigating Design and Technology (D&T) educators' engagement with educational research, past, present, and future, including initial teacher education, postgraduate studies and school-based inquiry. Participants were invited to respond to a survey by the Design & Technology Association (D&TA) research steering group (DTRSG), underpinned by three research questions that guided the study:

- **RQ1.** To what extent are teachers of D&T currently engaged with educational research?
- **RQ2.** Is there interest in the development of support from the D&T Association for educational research?
- **RQ3.** Where should the D&T Association prioritise educational research?

The DTRSG was established in 2021, when this survey was launched and this paper builds on an initial analysis of findings from the questionnaire at the Pupils' Attitudes Towards Technology (PATT39) in 2022 (McLain et al., 2022), which focused on four survey questions.

The majority of participants identified themselves as curriculum leaders (56.0%) and qualified teachers (35.0%), accounting for 72.6% of the responses – note that participants could select multiple roles and we assume that curriculum leaders are also qualified teachers (Table 1).

***Table 1 Current Role in D&T***

| Role | Main n (%) | Multiple n (%) |
|---|---:|---:|
| Middle Leader | 139 (50.2%) | 155 (56.0%) |
| Qualified Teacher | 62 (22.4%) | 97 (35.0%) |
| Senior Leader | 27 (9.7%) | 31 (11.2%) |
| Teacher Educator | 15 (5.4%) | 28 (10.1%) |
| Educational Consultant | 11 (4.0%) | 15 (5.4%) |
| Student Teacher | 5 (1.8%) | 5 (1.8%) |
| Retired | 4 (1.4%) | 4 (1.4%) |
| Educational Researcher | 2 (0.7%) | 10 (3.6%) |
| Early Career Teacher | 1 (0.4%) | 1 (0.4%) |
| Unqualified Teacher | 1 (0.4%) | 1 (0.4%) |
| Technician | 7 (2.5%) | 7 (2.5%) |
| Other | 3 (1.1%) | 2 (0.7%) |

62.9% of the participants were involved with secondary D&T education and 20.2% with primary (Table 2). Participants were able to identify multiple options for their current role(s), with educators working as consultants, teachers and researchers. Most respondents trained in England (89.9%), with minor representation from Northern Ireland (0.4%), Scotland (1.1%), Wales (3.6%) and others (5.1%) - including Australia (0.4%), India (0.4%), Nigeria (0.4%), Republic of Ireland (0.8%), and Zimbabwe (0.4%). Of the teachers working in schools, the majority worked in Academy or Free Schools (42.2%) and Local Authority Maintained schools (26.0%); with representation from Fee Paying (15.9%) and Grammar (3.2%) school settings.

***Table 2 Representation from the Education Phases***

| Phase | Number n (%) |
|---|---|
| Early Years | 11 (3.1%) |
| Primary | 72 (20.2%) |
| Middle | 3 (0.8%) |
| Secondary | 224 (62.9%) |
| Special | 3 (0.8%) |
| Further | 22 (6.2%) |
| Higher | 15 (4.2%) |
| Other | 6 (1.7%) |

Most responses came from qualified or trainee teachers, with almost two thirds (62.7%) being trained via a postgraduate route (Table 3). Half of participants (50.2%) indicated that they had completed a dissertation as part of their initial teacher education, with most of these (59.7%) focusing on D&T. Most participants (69.9%) had not completed a postgraduate qualification since qualifying to teach, with only 14.5% (n=12) undertaking a full Masters and 3.6% (n=3) a doctorate, indicating a limited number having engaged with formal, structured research since qualifying.

Almost half of the responses (48.4%) were from participants who were in service for up to 30 years (Table 3). As an overall percentage, participants with more than 5 years' service were more likely to be very interested in D&T research, with the strongest representation from the categories with 6-10 (71.4%), 11-15 (57.7%) and 16-20 (63.0%) years.

***Table 3 Years In-Service***

| Years | Number n (%) |
|---|---|
| 0-5 | 40 (14.4%) |
| 6-10 | 35 (12.6%) |
| 11-15 | 52 (18.8%) |
| 16-20 | 46 (16.6%) |
| 21-25 | 44 (15.9%) |
| 26-30 | 36 (13.0%) |
| 31-35 | 8 (2.9%) |

## Literature review

Stenhouse (1975), a foundational proponent of the idea of teachers-as-researchers, highlighted the gap between teachers' ideas, aspirations, and actions as the problem of evidence-informed practice, emphasising the need to acknowledge and investigate our failures. This approach espouses the view that good teaching is experimental and reaches for improvement (Rudduck & Hopkins, 1985), a far cry from the current focus on professional standards (DfE, 2011) and inspection frameworks (Ofsted, 2022) that take a performative stance towards teacher effectiveness. Nevertheless, this is the context that teachers in England find themselves in and, as mentioned earlier, there is also the DfE and Ofsted current focus on evidence-based practice. Therefore, it is important to build research capacity in the teaching workforce, not merely providing access to appropriate research, but by equipping teachers with the knowledge to interpret and apply it (Cain 2019; Davis 2020).

There have been attempts in the recent history of education in England to encourage and facilitate teacher-researchers. The UK government funded the Best Practice Research Scholarship (BPRS) programme between 2000 and 2003 that was intended to build research capacity and engagement in schools (Furlong & Salisbury, 2005). Approximately 3000 scholarships were awarded to classroom teachers. However, Furlong and Salisbury's evaluation of a sample of teacher research, found that the emphasis of most projects was on improving practice in individual schools, rather than on knowledge generation and exchange. Therefore, the learnings from this potentially impactful initiative were somewhat limited to the local settings and serendipitous cross pollination of ideas. A lack of rigour and effective dissemination resulted in missed opportunities for the wider teaching communities to learn from the funded research. One of Furlong and Salisbury's recommendations was that a combination of mentoring, funding, and formal facilitation of research in schools would have a greater chance of success.

An example of this taking place has been described by Skogh and de Vries (2013), outlining a funded doctoral programme for teachers in Sweden. This study focused on the learnings from technology education teacher research. The programme aimed to bridge the gap between academia and schools. Themes emerging from the evaluation of this and similar projects emphasise the importance of collaboration, impact, mentoring and access. Collaboration is important both for planning and funding school-based research, and having a clear understanding of impact, including classroom practice and learners' attainment. There is a need for a supportive and purposeful community that engages teachers working together with experienced researchers in a symbiotic and robust mentee-mentor relationships. Finally, is fundamental importance that teacher-researchers have access to research findings (often hidden behind a paywall only accessible to HEIs) and the resources to facilitate sustained study to inform and improve classroom practice.

These findings resonate with the apparent intentions of the DfE for schools in England, with the exception of any direct reference to the role of HEIs in providing support and expertise. A recent White Paper states that there is "a rigorous commitment to using, building and sharing evidence so that every school knows 'what works' for all of their children; and a focus on enabling collaboration between teachers, schools and wider children's services" (DfE, 2022, p.8). As mentioned earlier, the current focus from the DfE and Ofsted is on educational research derived from cognitive science and randomised controlled trials. However, critics point out the limitations of these approaches to handle the complexities of human behaviour and volition, as well as being relatively unproven in real world contexts. The so-called 'what works' approach, whilst appearing on the surface to be pragmatic, could be incorrectly inferred to provide concrete answers to every classroom circumstance and underplay the importance of teacher experience and expertise, as well as a wider range of research methodologies (Biesta, 2010).

In order for teacher research to happen, teachers need to be given time and training to plan, do, analyse and share research (Herbert-Smith, 2022; Stremmel, 2007). The benefits of becoming involved in research include a potential increase of reflectiveness and criticality in teaching, as well as openness, and commitment to professional development (Stemmel, 2007).

The next section explores the theoretical framework being used to analyse the findings presented.

## Theoretical Framework

The findings of the questionnaire have been analysed using Self Determination Theory (SDT) (CSDT, 2023). SDT provides "a broad framework for the study of human motivation and personality" and is concerned with the experience of *competence*, *relatedness*, and *autonomy* by the individual. These three factors are argued to underpin intrinsic motivation and engagement, as well as promote "enhanced performance, persistence, and creativity" (see also Maslow, 1943, 1954). The findings have been analysed using these three core factors.

SDT considers human beings' need for **competence** as one of the three basic psychological needs, and a motivating factor for the process of learning and engaging with our environment (Ryan & Deci, 2017). Associated with competence is a sense of ability to organise oneself and initiate action. Factors that undermine competence are those that remove or limit agency and confidence, irrespective of innate or developed ability. Performing well at a task does not necessarily result in a feeling of competence, especially where a lack of self-initiation and/or self-regulation involved.

**Relatedness**, as the second basic need, asserts that a main aim of human behaviour is to foster belonging and significance. Conversely, there is also a need "to avoid rejection, insignificance, and disconnectedness" (Ryan & Deci, 2017, p.96). Therefore, the social interactions that teachers have with local and national school cultures can result in behaviours, beliefs and values that are shaped and internalised by the predominant views of those in a position to grant approval and acceptance, as well as those of peers. The more that a human being has a sense of belonging or relatedness in a social context, the more likely they are to internalise the beliefs and values of the culture; rather than behaviours being self-regulation of external motivation (introjected regulation) or imposed and regulated from outside (external regulation).

The third basic need, **autonomy**, "concerns the extent to which people experience their behaviour as volitional or as fully self-endorsed, rather than being coerced, compelled, or seduced by forces external to the self" (Ryan & Deci, 2017, p.97). Being autonomous is not the same as being independent in SDT, the latter implying separateness and non-reliance on others, whereas autonomy is seen as *acting* with autonomy and also interdependent in key relationships with individuals and groups. It is not considered as an act of rebellion or defiance against an authority, but the ability to act with volition.

## Research Design

The research design for this study was convergent mixed methods, collecting qualitative and quantitative data at a single data collection point (Creswell & Creswell, 2018). An online questionnaire was used to enable a wide range of participants to respond to the survey. The benefits of questionnaires include the potential to reach a wider audience and gather a large amount of data. However, limitations include the potential gap between what participants say or believe and how they act. The research paradigm adopted for this study was pragmatism, being concerned with the actions and behaviours of D&T educators in their personal contexts and situations (Creswell & Creswell, 2018). The researchers' axiological position is that educational research is important and has value, and that there is a need for systematic investigation of D&T education. This is an inductive study, seeking to reveal and explore D&T educators' views and experiences (Guba, 1990).

The study had ethical approval from Liverpool John Moores University and followed British Educational Research Association (BERA, 2018) guidelines. The initial invitation to participate was sent through the D&TA mailing list, with gatekeeper consent from the CEO and Board of Trustees. The data was collected over a period of four months spanning the end of the summer and beginning of the autumn terms in 2021. The initial sampling method was purposive, with social media being used for snowball sampling to maximise the return rate. The sample size was 277, which represents approximately 15% of the Association's membership at the time of completion of the survey. At a confidence level of 95% and confidence interval of 6, this sample was considered to be sufficient for this initial study.

## Findings

With our focus on SDT as our approach to analysing and understanding D&T educators' interests and relationship with research, we explored the extent to which there was evidence of *competence*, *relatedness* and *autonomy*.

### Competence

Competence is a motivating factor for the process of learning and engaging with our environment. Teachers need to have a secure body of conceptual and procedural knowledge about teaching and learning to be *and* feel competent in the classroom. The same is true for researchers, who have a different, yet complimentary body of knowledge. Key factors associated with competence are a sense of being able to self-organise and take action, and feeling competent is as important in SDT as effective action. Therefore, undermining competence removes or limits agency. Performing a task well (*being* competent) is different to a feeling of competence, particularly in circumstances where the ability to self-initiate and/or self-regulate has been impinged.

There was a high level of interest in generic (91.7%) and D&T specific (96.4%) research (Table 4), with the proportion of approximately half switching from quite interested in generic to very interested in D&T research, but this does not automatically lead to or infer a sense of competence.

***Table 4. How interested are you in educational research?***

| **Level of interest** | **Very interested** | **Quite interested** | **Quite disinterested** | **Very disinterested** |
|---|---|---|---|---|
| In general, | 114 (41.2%) | **140 (50.5%)** | 20 (7.2%) | 3 (1.1%) |
| Specifically D&T | **150 (54.2%)** | 117 (42.2%) | 8 (2.9%) | 2 (0.7%) |

When asked whether they use D&T educational research to inform their practice, or as part of their role, almost half of participants (48.0%) stated that they used research some of the time (Table 5). A relative lack of confidence or competence could be inferred, when compared to those who stated that they used it all the time (11.2%), particularly when contrasted with the responses when questioned about their interest in D&T research. The correlation between interest in and frequency of use was low at 0.3 (Table 6), suggesting a disconnect between intention and application, which is illuminated by qualitative comments discussed below.

***Table 5 How much do you use D&T educational research?***

| Frequency of use | Number n (%) |
|---|---|
| All the time | 31 (11.2%) |
| Some of the time | 133 (48.0%) |
| Rarely | 80 (28.9%) |
| Not at all | 26 (9.4%) |
| Not applicable | 5 (1.8%) |
| Other | 2 (0.7%) |

Participants who stated that they used D&T research some or all of the time were asked about the research topic(s) they were interested in, and those who rarely or never used it were asked to comment on their reasons. These qualitative responses are discussed below. However, whilst there was a strong interest in D&T related activities (such as ideating, realising, and critiquing), the next highest rated area was into generic research from cognitive sciences, mirroring certain negative comments made by the ‘rarely or never use’ participants. Table 6 presents the Pearson Product Moment Correlation between the questions relating to participants’ interest in generic research (Q6), D&T specific research (Q7), frequency of use of D&T research (Q8) and confidence conducting research (Q9). This illustrates a weak correlation between how positively participants answered these four questions, with the exception of a strong positive link between an interest in generic and D&T research. High levels of interest were not followed by high levels of self-reported competence in using and doing research.

***Table 6 Correlations between interest in, use of and confidence***

| | Q6 | Q7 | Q8 | Q9 |
|---|---|---|---|---|
| Q6 Interest in genetic research | 1 | | | |
| Q7 Interest in D&T research | 0.64548214 | 1 | | |
| Q8 Use of D&T research | 0.34350632 | 0.30184877 | 1 | |
| Q9 Confidence researching | 0.41699711 | 0.30832652 | 0.31164663 | 1 |

103 participants gave responses for why they ‘rarely or never use’ D&T education research. As one might expect, the comments were overwhelmingly negative in terms of perceived or actual competence with educational research (90.2%). However, the more positive (4.9%) or neutral (4.9%) responses provided some interesting insights. One of the ‘rarely use’ respondents demonstrated a high level of competence, having *“taught education research methods in the context of D&T at undergraduate, Masters and PhD levels”* as a retired academic in higher education. Another stated that their *“previous school were not huge advocates of DT [sic.] research and so I became involved in general teaching and learning project about metacognition”* but had been involved with a university *“research project about girls vs boys and creativity and nature vs nurture”*; and another stated that they engaged with *“more generic research on pedagogy which informs my teaching”*. So, it would be misleading to infer that rarely or never using D&T research equates to incompetence for every participant.

Of the more neutral comments (n=5), two expressed a lack of interest in D&T research and three a lack of relevance to their current role. One of those who was not interested stated that they were satisfied with the knowledge they have, suggesting a level of ambivalence towards knowledge generation through research; although they did mention lack of time and access, which came up frequently in more negative comments. The comments revealed a lack of motivation to develop or demonstrate competence, for example one participant stated that their *"job does not require it. I occasionally see it in the press but most of it irritates me"*. Another stated that they were happy with the knowledge they have. In SDT, a sense of agency and motivation go hand-in-hand with the idea of competence. Therefore, these respondents did not appear conflicted or dissatisfied with their lack of engagement, and (potential) incompetence.

Of the 93 more negative comments, the strongest themes were *time and workload*, followed by *awareness, access and relevance* (Table 7). A small number of comments inferred a need for *training* to access, interpret and apply research, and others on the negative implications of whole school *policy* on research engagement e.g., *"too many whole academy policies based on other schools that don't directly relate to DT [sic.]"* and a *"conflict with school teaching policy/methods"*.

***Table 7 Factors affecting use of D&T research***

| **Factors** | **Instances (n)** |
|---|---:|
| time | 42 |
| awareness | 26 |
| access | 24 |
| relevance | 17 |
| training | 9 |
| policy | 8 |
| workload | 7 |
| motivation | 6 |

Even within the negative comments, there was evidence of a desire to engage with research, and possibly frustration at the obstacles in the way.

> *"Keen to try new things and keep up to date as long as they are practical…"*

> *"I would like to read more right across the publication options. I do feel it would help our department and my teaching; I would hope to do more this year…"*

A feeling of incompetence can be associated with the ability to initiate, organise and regulate activities by oneself being hindered, e.g., external factors prohibiting or discouraging autonomous action. A variety of factors affecting the competence of participants in relation to D&T research could be considered as external, such as time, training, policy and workload (as they are largely outside of the control of the individual educator). Collectively these account for approximately half (47.48%) of the responses, with time and workload representing 35.25%, issues related to policy 5.76% and a lack of training 6.47%. All were perceived to affect engagement with D&T research. Of the more internal factors, a small number of participants view research as irrelevant (12.23%) to their current situation or were unmotivated or disinterested (4.32%), self-selecting themselves to not develop or nurture competence. In that blurry boundary between internal and external factors, over a third of the responses cited a lack of awareness to (18.71%) or access to (17.27%) D&T research.

Whilst it could be argued that teachers could (and in a small number of cases do) engage with research, considered together with the perceived lack of training, there is a strong case for this being an area that could be addressed externally - i.e. resources to increase the visibility of quality D&T research and the tools to access and use it with confidence. One participant commented that they *“have found that there is very little subject specific research for D&T that [they] find relatable”*. Irrespective of whether the research is available, it is clearly not the experience of this D&T teacher, and many others who lack competence through a lack of knowledge of how to find quality D&T research.

Issues of time and workload can be outside of direct control of schools or teachers. Consequently, a response that merely provides access to peer-reviewed research articles is unlikely to address the relative lack of engagement. Any solution to the problem must take account of the governable variables, such as producing resources requiring teachers to invest less of their valuable time to digest, synthesise and apply research findings in their classroom practice. Several participants were interested in pursuing postgraduate studies to undertake research, but thwarted by schools’ pressing concerns on examination results, Ofsted inspections, Government prescribed theories, and core subjects, with limited support in terms of time and funding. This was not the case across the board as there was evidence of schools with a culture of research, and time allocated for research. But the overwhelming response was that support to develop competence is not generally available for D&T educators to feel confident as consumers and users of subject-focused research. In the words of one secondary curriculum leader:

> *“More teachers would be willing to engage in educational research if time was given for this. Unfortunately, it is another thing to fit in and impacts on work life balance.”*

When asked how confident they felt undertaking educational research (Q9), over two thirds expressed that they were very (18.8%) or quite (48.7%) confident (Table 8). There is an interesting relationship between the responses in Tables 4 (application) and 8 (confidence), with a relatively weak positive correlation of 0.31 between self-reported application of and confidence undertaking educational research (Table 6).

***Table 8 Levels of confidence with research***

| Confidence level | Number n (%) |
|---|---:|
| Very confident | 52 (18.8%) |
| Quite confident | 135 (48.7%) |
| Quite unconfident | 70 (25.3%) |
| Very unconfident | 26 (7.2%) |

Whilst over half of the participants were *very* interested (54.2%) in D&T educational research (Q7) (Table 4), the correlation between this and application was low (0.34), and confidence low to moderate (0.42), indicating that there is a gap between motivation and practice (Table 8, above). A significant minority (43.3%) gave the same response for both their current use of D&T research (Q8) and their confidence in undertaking research (Q9), with about one third (34.7%) stating a higher level of confidence undertaking research than frequency of using it. However, as indicated above, a lack of time to engage with and access research were stated as key barriers to using it (Table 7). The slightly higher correlation between interest and confidence, compared to interest and application, could be associated with the lack of time, awareness, and access, suggesting that interventions and support that reduce time and effort required to access research findings could have more impact than simply training teachers to be more confident consumers and users of research, factors that could support teachers' sense of relatedness and autonomy, as well as competence.

**Relatedness**

The sense of relatedness, in SDT, could also be described as a sense of belonging, and is significant for creating and developing a community of educators interested in using or undertaking research in D&T.

SDT focuses on the degree to which human behaviour is self-motivated and self-determined. Good education relies on educators being highly motivated and desire to make a positive difference in peoples' lives. D&T is a subject that revolves around collaboration amongst several areas of expertise. For example, in a small number of qualitative responses (n=15), there was a focus on the D&T content knowledge, such as food, textiles, etc., rather on pedagogical approaches. However, the two most popular foci for both middle leaders and classroom teachers were pedagogical (n=34) and strategies for ideating (designing) (n=27).

***Table 9 Interventions to Support D&T Educators***

| | **I would definitely use this** | **I would probably use this** | **I would probably not use this** | **I would definitely not use this** |
|---|---|---|---|---|
| A web portal with links to D&T related research. | **159 (57.4%)** | 100 (36.1%) | 11 (4.0%) | 7 (2.5%) |
| Guidance on conducting D&T research in the classroom. | **124 (44.8%)** | 113 (40.8%) | 28 (10.1%) | 12 (4.3%) |
| Online research seminars with experienced D&T researchers. | 108 (39.0%) | **130 (46.9%)** | 31 (11.2%) | 8 (2.9%) |
| ResearchMeet events with D&T educators presenting their research. | 92 (33.2%) | **118 (42.6%)** | 53 (19.1%) | 14 (5.1%) |
| Research networking events. | 82 (29.6%) | **116 (41.9%)** | 68 (24.5%) | 11 (4.0%) |
| Mentoring for research. | 61 (22.0%) | **109** (39.4%) | 91 (32.9%) | 16 (5.8%) |
| Writing retreats / workshops. | 48 (17.3%) | 73 (26.4%) | **113 (40.8%)** | 43 (15.5%) |

As noted in the findings on competence, there was a strong sense of relatedness to educational research being an area of interest; with 91.7% of participants interested in educational research in general and 96.4% interested in D&T specific research (Table 6). This was further supported by 93.5% interested in a web based portal for D&T research, as the most popular of the suggested interventions (Table 9). A smaller, but significant, percentage of 85.6% said they would definitely or probably use guidance to support them in conducting D&T research within the classroom, suggesting a strong desire to embed subject specific research into their practice.

When participants were asked to rate 7 potential interventions to support them to engage with research, the most popular option was access to an online portal to foreground D&T related research, with majority stating that they would definitely (57.4%) or probably (36.1%) use the resource (Table 9). This was closely followed by guidance on conducting research in the classroom, and slightly fewer who would definitely (44.8.4%) or probably (40.8%) use the resource. Linked to the data discussed above, these options represent the most controllable and time efficient way for busy teachers to access support in their own time and at their own pace. Two options involved with research findings being shared also had a strong approval rate, with seminars from experienced D&T researchers representing a combined 85.9% of the 'use' responses and ResearchMeets at 75.8%. The interventions that could be considered as more time consuming, were less popular, but the approval rate for networking events and mentoring was still noticeably high, indicating that the interventions that participants related most to were those that bridged the gap between interest in, and using research in the classroom. The opportunity to connect with peers and more experienced colleagues, whilst rated lower than those that related to the participants classroom practice, still had a relatively high approval rate, indicating an interest in belonging to a community of practice for D&T research. Even the 'least' popular intervention, writing retreats and workshops had 17.3% of the participants responding that they would 'definitely use' these. If these results can be trusted, this is positive and indicates a desire to belong to a community where subject research is valued.

Table 9 also highlights that there are barriers to engaging with research. The highest rated interventions are potentially the most easily relatable and accessible to busy teachers who are keen to belong to a D&T research community as a consumer and user of research, but possibly not ready to engage as an investigator, linking to aspects of relatedness that emphasise humans' natural growth toward positive motivation, development, and personal fulfilment.

Of the 164 participants that stated that they used D&T educational research to inform their practice or as part of their role 'all of the time' (n=31) or 'some of the time' (n=133), there was a range of different areas of research interest. There were 143 qualitative responses to the question "What research topics are you interested in?" (Q8b.). The initial open coding identified 48 themes, which were refined down to four overarching themes (Table 12).

***Table 10 Themes of Research Interest***

| Theme | References (n) |
|---|---|
| Pedagogy | 161 |
| Curriculum | 98 |
| Equality, Diversity and Inclusion | 51 |
| General | 29 |

A significant proportion referred to pedagogical (n=161) and curricular (n=98) research (Table 10) providing an insight to the areas that they most closely related to. However, there were also a significant number of references to research that could be categorised as equality, diversity and inclusion (EDI), which reflects the increased attention this has received in recent years and a desire to include all learners in D&T activities - both indicators of relatedness. There were a wide range of different topics, and further analysis of the broad themes in Table 10 revealed the majority of responses related to fundamental D&T activities of ideating, realising and critiquing (alternatively designing, making and evaluating) (Table 11) suggesting a high level of relatedness to subject specific research themes. However, the second highest category related to more general cognitive sciences research, such as metacognition and retrieval, which could suggest a degree of introjected regulation. It is perhaps unsurprising that themes from the cognitive sciences featured highly in responses, with this body of research currently being proscribed by the DfE and Ofsted, in England.

Qualified teachers who did not hold a management post also mentioned designing, making and creativity at a similar rate (19.6%) to the broader educational themes - as their top rated area of interest - compared to those with management responsibility (13.0%) - as their second highest after pedagogy in general (19.6%). The majority identified more than two different areas of research, which could indicate a degree of ease with which they relate research to day-to-day classroom practice.

***Table 11 Sub-themes of Pedagogical Research Interest***

| Pedagogy sub-theme | References (n) |
|---|---:|
| Fundamental D&T activities | 41 |
| Cognitive science concepts | 27 |
| Information and communication technology | 20 |
| Assessment | 15 |
| Motivation | 10 |
| Project-based learning | 8 |

Three quarters of the responses represented in this sub-theme linked to activities associated with ideating, such as methods of teaching the skills and knowledge focussed on co-creation, design thinking, empathy, iterative design, modelling, and sustainable design; as well as:

> *"how recording the design process disrupts iterative design"*
>
> *"higher level thinking skills within the iterative design process"*
>
> *"convergent and divergent thinking through D&T and creative problem solving"*

For participants who stated that they do not (9.4%) or rarely (28.9%) use D&T educational research (Table 5), the most frequent reasons were time (n=42), awareness (n=26) and access (n=24) (Table 7). However, the fourth category with most frequent mentions was regarding relevance (n=17), intimating that educational research was not something that they related to or critical to their communities of practice. A small number of these participants cited a lack of training (n=9), the restrictiveness of school policy (n=8), workload (n=7) and a lack of motivation (n=6), suggesting that they did not see research as directly related to their core responsibilities as educators.

These barriers, though present, should not detract from the evidence that most participants were interested in educational research. However, there is a gap between aspiration and action, and any solution must be relatable to educators' daily experience and build a sense of belonging in a community of teacher-researchers. SDT supports this analysis, illustrating how educators want to support their profession through professional development for the good of their own classrooms and practice. Though there were clear reasons as to why educators were not engaging with research as consumers, users and/or investigators, it appears that there is a desire to be involved. The participants who expressed an interest in engaging with future research identified a wide range of themes. The NVIVO (Lumivero, 2020) generated word cloud in Figure 1 illustrates the frequency of the 500 most common word matches, including synonyms. Most of the themes were directly linked to D&T, which suggests that related to subject specific research. D&T research topics ranged from the role of practical work to design, to knowledge, to gender, and sustainability. Of the most directly D&T related word in Figure 1, 'design' was associated with the synonyms: designing, designs, planning, project, projects, purposeful; with a weighted percentage of 4.7%, behind the more general 'learning' at the top (synonyms: instruction, know, knowledge, learn, reading, teach, teaching) at 5.3%.


***Figure 1 Word cloud of research interests***

**Autonomy**

A key aspect of the extent to which educators chose to access, use or conduct research is the level of autonomy they perceive themselves to have. In relation to the survey conducted, a range of insights emerge into individual decisions and actions in respect of the level of autonomy an individual feels. No questions in the survey explicitly sought autonomy related perspectives, but a number of questions resulted in such insights being revealed. These insights appeared across what could be seen to be a continuum from respondents expressing a positive sense of autonomy such as agency to those making negative statements that signalled a sense of helplessness. Through qualitative data analysis, statements were categorised into one of three points across the continuum – showing autonomy, aspirational and lacking autonomy.

*Showing autonomy* comments signalled autonomy linked to feelings such as agency, acting in relation to own beliefs, goals and values, self-determination, self-sufficiency, independently choosing own behaviours, actions, and decisions, confidence. *Aspirational* comments were also positive, tending to indicate how a respondent would like to operate, using terms such as plan to, hope, ambition, wish, desire, intention and inclination. *Lacking autonomy* comments indicated feelings such as lack of control, helplessness, powerlessness, being incapable, being coerced.

Four questions revealed aspects of autonomy. The first of these was a four part question starting with *Do you currently use any D&T educational research to inform your practice or as part of your role?* Participants selected from a drop down list consisting of: *Yes, all of the time; Yes, some of the time; Rarely; and Not at all* (Table 5). Statements that showed aspects related to autonomy were revealed in the third part of the question: *Please tell us why you do not or rarely use D&T education research*. From a total of 73 comments linked to autonomy, not surprisingly, the majority of the comments indicated a lack of autonomy, with just a single comment indicating a level of autonomy through showing a keen commitment to research and two aspirational comments indicating a desire to engage with research, but also highlighting challenges as shown in the comments below.

> *"I have focussed on core subjects as part of my career development to date. As subject lead I now have a keen interest and will be engaging with research." (keen interest, will engage)*
>
> *"I would definitely like to more, but it is difficult due to lack of time and workload."*
>
> *"Keen to try new things and keep up to date as long as they are practical and don't add work"*

The vast majority of comments showed a lack of autonomy, lack of control, helplessness and a level of coercion as illustrated in the following three comments.

> *"We are very focused on more general pedagogical research in our school, for example of literacy, knowledge acquisition and recall etc. This leaves little time for extras and DT specific research needs to be pushed to us because we are not good at going looking for it." (lack of control, incapable)*
>
> *"Not knowing how or where to access useful research." (helplessness)*
>
> *"time constrains, too many whole academy policies based on other schools that don't directly relate to DT that we have to implement" (lack of control, being coerced)*

The question that followed shifted the focus to levels of confidence in undertaking research, asking respondents: *How confident do you feel undertaking educational research? Do you have any comments?* The first part of the question gave respondents a drop down list: *very confident; quite confident; quite unconfident; very unconfident* (Table 8, 12). This was followed by asking for any comments on their choice. Table 12 shows the numbers of respondents answering the first question on levels of confidence and also the numbers adding comments.

As can be seen from the table, only a small number of respondents added comments (8%). Despite the small numbers, a noticeable aspect is that more comments have been made by those feeling confident about research, but also that even within this group there is evidence of a lack of autonomy. The following two statements illustrate this, both made by teachers who are very confident in their research skills, both secondary teachers with considerable experience, one indicating agency, confidence, independent actions - *"I have a science* *background and those research skills transfer well. I have helped several colleagues/PGCE students devise experiments when they needed to gather data that is measurable. Think this sounds like a great project",* the other lacking autonomy, expressing a lack of control: *"Design and technology teachers have a tough time keeping up with relevant research as our subject content changes daily - when did Pythagoras theory last change?! Not much time in PPA* [Planning, Preparation and Assessment] *to do this*". Aspirational comments were the most common and spread from confident to very unconfident, for example an early career primary teacher showing ambition and aspiration, stating *"I am looking to develop my confidence with research as part of my personal development as an Early Career Teacher."* Comments indicating a lack of autonomy also highlighted a sense of frustration with education policies that created a lack of control and power - *"Since taking up my current role in an academy (3 yrs ago) I feel like I work in an educational factory - told what to teach and how to teach it. It's Like everything is done to tick a box".*

***Table 12 Confidence levels and indications of autonomy***

| | **Levels of confidence** | **showing autonomy comments** | **aspiring comments** | **lacking autonomy comments** | **Totals comments** |
|---|---|---|---|---|---|
| Very confident | 57 | 6 | 2 | 1 | 9 |
| Quite confident | 143 | 2 | 10 | 4 | 16 |
| Quite unconfident | 71 | 1 | 3 | 1 | 5 |
| Very unconfident | 20 | 0 | 1 | 3 | 4 |
| **TOTALS** | 291 | 9 | 16 | 9 | 35 |

The third question providing insights into levels of autonomy asked: *Have you conducted, presented or published educational research? Do you have any comments to explain your response?* The first part of the question resulted in 68% of respondents stating that they had not conducted, presented or published research. Despite the high numbers not having done so, both groups provided comments to explain their answers and once again insights into showing or lacking autonomy were revealed.

***Table 13 Conducting, presenting, publishing research***

| | **YES** | **NO** |
|---|---|---|
| Numbers conducting, presenting, publishing research | 94 | 197 |
| Comments to explain | yes | no |
| Showing autonomy | 24 | 0 |
| Aspiring | 5 | 11 |
| Lacking autonomy | 1 | 4 |
| **TOTAL COMMENTS** | 30 | 14 |

Those having undertaken research were most likely to indicate a level of autonomy, often reported with confidence. An example of this from a secondary teacher refers to research going against a mainstream view, investigating the *"role of social media in supporting teaching and learning at a time when some educators/schools are trying to ban mobile technologies and social media in schools"* - indicating agency, acting in relation to one's own beliefs, goals and values, independently choosing behaviours, actions, and decisions and confidence. The majority of comments from those who had not conducted, presented or published research fell into the aspirational category, showing ambition to engage with research, as illustrated by this secondary teacher: "*It is a recent interest for me and I'm not sure where to start. I generally research small-scale in my classroom"*; or a desire to engage, such as: "*I would love to get involved"*, by a primary/secondary teacher. Inevitably there were those expressing helplessness and a lack of capability, as was stated by a secondary teacher *"I wouldn't know where to start, it seems like it would be out of reach."*

A final question "*Do you have any other comments or suggestions related to educational research?*" provided an opportunity for open comments and 21 reflected some aspect of autonomy. The majority (n=16) showed a lack of autonomy, and control, often coupled with a level of frustration, for example, *"Senior Leadership support that we need to research, but then do not allow the time or do not have the budget to do it.", "I have applied to start a Masters 3 times but English and Maths teachers have been selected. I was informed this is due to the subject being core", "Research is often whole school based rather than subject specific and as such can often overlook the different requirements of more practical subjects such as D&T". This contrasted with a small number of positive comments that supported autonomy in research such as acting on own beliefs, values as was contributed by a secondary school head teacher stating that " we have a research culture at the school where every teacher produces a research project on a theme of their choosing"*

The demographic data collected in the survey enabled us to explore the extent to which comments were impacted by age group taught (primary, secondary or tertiary) The examples shown above, are drawn from across the spectrum of demographic dat. No constituency was exempt from indicating autonomous behaviour or experiencing a lack of autonomy in respect of engaging with D&T education research.

## Discussion

Comparing the findings from this study with the aims and assumptions of education policy makers in England (DfE, 2017; Ofsted, 2020), it is clear that there are some similarities and differences in what is valued and sought by teachers of D&T. It is evident that D&T educators share the view that being research-informed benefits teaching and learning in schools. However, this is where the similarities end. Most of the participants did not feel that they have access to relevant and high-quality D&T research readily available, which they value even more than generic educational research. Nor do they feel they can actively engage with and apply it, with a variety of reasons stated - time, awareness, access, and relevance being the main barriers. There was little consistency of experience and engagement (competence) following directly on from interest, and the overwhelming response was that support is not generally available (relatedness) for D&T educators to feel confident as *consumers*, *users*, and/or *investigators* of subject-focused research (autonomy). The analysis of data from all three perspectives (competence, relatedness, and autonomy) highlights that teachers do want to engage in research, which we find extremely promising and something that should motivate future interventions and opportunities related to D&T research capacity and engagement. Yet, in the current climate, a general lack of confidence engaging with research (competence), and opportunities to network with other teachers and researchers (relatedness), results in a feeling of disconnect between interest and action (autonomy). It is clear that any future interventions should focus on building confidence and connectivity, facilitating agency for teachers to self-regulate their classroom environment, drawing on a wider body of research findings alongside their own practitioner inquiry.

However, it is also clear that interventions that focus solely on providing access to training on research and peer-reviewed journal articles (considered to be the gold standard of research) may not be the most effective approach. The prevalence of factors associated with the pressures of time and workload, in the current context of schools in England (inc. pressures associated with high stakes inspection and testing, teacher recruitment and retention, and lack of access to professional development), challenges those who support teachers of D&T (e.g. the D&T Association, consultants and academic researchers) to think again about a cogent, coherent, and connected strategy to engage teachers with subject research. For example, rather than merely training teachers how to read and interpret a research article (which in our opinion does have value), a more cogent approach might be to provide them with ready access to executive summaries, synthesising the key learnings from research related to practical classroom scenarios, written for busy professionals and focusing on impact in the classroom. This was reflected in the proposal for an online portal with access to research being ranked as the most popular intervention. This is an option where teachers can self-organise and self-regulate their engagement with research and could result in an increased sense of agency (autonomy and competence).

We propose that reducing the time and effort required to access high-quality and impactful research could be more successful in achieving the goal of a more research literate community of D&T teachers, than simply training teachers to be more confident *consumers* and *users* of research. This does not negate the need for higher levels of engagement with research, but this will be of interest and relevance to a smaller and self-selecting subgroup of the community. The push from teachers for high-quality D&T research is not *against* generic research (such as the government sanctioned cognitive sciences), but for a *rebalancing* of the diet of research findings that are available and promoted by authorities. Interventions such as networking and ResearchMeet events provide opportunities for teachers to develop as consumers and users of research, but also to belong to a community where teacher-research is encouraged and fostered. Teachers who want to go further as investigators in their classrooms (autonomy) have a greater chance of accessing mentoring and other support to advance their skills (competence) by being part of such communities (relatedness). However, the challenges to teachers' workload should be borne in mind with any strategic approach to increasing D&T teacher competence, relatedness, and autonomy outside of their core teaching duties. The aim being to make it more straightforward to incorporate evidence-based practice into every D&T classroom.

In terms of the research questions, it is evident that the level of interest outstrips the engagement with education research (RQ1), but there is strong interest in a range of interventions to support (RQ2). The answer to the research question on where the D&T Association should prioritise educational research (RQ3), is more complex and has only been touched on in this article. However, it is clear that a good proportion of the participants have an interest in pedagogical research exploring the fundamental D&T activities of ideating, realising, and critiquing, particularly the former. But this should not be at the expense of nurturing a rich research landscape, including curriculum and EDI matters, as well as contextualising cognitive sciences research in D&T.

## Next steps

Since the survey was conducted, things have started to progress; the D&T Association's membership has grown exponentially, especially in Primary schools, possibly as a result of school inspections seeking evidence of a 'broad and balanced' curriculum. The DTSRG has been established, and a website (researchingdandt.co.uk) has recently been launched with links to books, podcasts and websites that will assist D&T teachers in accessing subject specific research. The DTRSG, with the support of the D&T Association now hosts bi-monthly online ResearchMeets, providing opportunities for presentations, discussions and information sharing. But the question remains - how do we ensure that individual schools see the value of subject specific research that can lead to personalised Professional development for teachers that will develop the subject and promote the broad and balanced D&T curriculum that will develop D&T capability. The survey has provided insights into needs, opportunities, barriers and challenges. Next steps are now to use the insights gained to strengthen the competence, relatedness, and autonomy of the D&T community.

## Acknowledgements

The authors would like to acknowledge the other members of DTRSG who are working together to highlight D&T research for teachers: Dr Brendan Anglim (Ampleforth College), Lesley Morris (former D&TA Chair of Trustees), Bill Nicholl (University of Cambridge), Tony Ryan (Design and Technology Association), Rebecca Topps (St George's Academy) and Dr Debi Winn (Northstowe Secondary College). This article builds on and extends the analysis in a paper first presented at the PATT39 technology education research conference (McLain et al., 2022).

## References

BERA. (2018). *Ethical Guidelines for Educational Research* (4 ed.). Retrieved from https://www.bera.ac.uk/publication/ethical-guidelines-for-educational-research-2018 [accessed 28/04/2023]

Biesta, G.J.J. (2010). Why 'What Works' Still Won't Work: From Evidence-Based Education to Value-Based Education. *Studies in Philosophy and Education*, 29(5), 491–503. https://doi.org/10.1007/s11217-010-9191-x

Cain, T. (2019). *How research can inform teachers and teaching in schools* [blogpost]. Available at https://www.bera.ac.uk/blog/how-research-can-inform-teachers-and-teaching-in-schools [accessed 28/04/2023]

CSDT (2023). Theory: Overview [webpage]. *Centre for Self-Determination Theory*. Available at https://selfdeterminationtheory.org/theory/ [accessed 28/04/2023]

Creswell, J.W. & Creswell, J.D. (2018). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (5th ed.). London: SAGE Publications Ltd.

Davis, A (2020). Making teaching more research-informed: Some challenges. *Impact, Issue 10: Developing Evidence-informed teaching techniques to support effective learning*. Available at https://my.chartered.college/impact_article/making-teaching-more-research-informed-some-challenges/ [accessed 28/04/2023]

DfE (2022) Opportunity for all strong schools with great teachers for your child, Retrieved from https://www.gov.uk/government/publications/opportunity-for-all-strong-schools-with-great-teachers-for-your-child [accessed 5 August 2023]

DfE (2017). *Evidence-informed teaching: an evaluation of progress in England Research report* [report]. Available at https://www.gov.uk/government/publications/evidence-informed-teaching-evaluation-of-progress-in-england [accessed 28/04/2023]

DfE (2013). *Building Evidence into Education* [report]. Available at https://www.gov.uk/government/news/building-evidence-into-education [accessed 28/04/2023]

DfE (2011). *Teachers' Standards: Guidance for school leaders, school staff and governing bodies*. Available at https://www.gov.uk/government/publications/teachers-standards [accessed 28/04/2023]

EEF (2023). *Educational Endowment Fund* [website]. Available at https://educationendowmentfoundation.org.uk/ [accessed 28/04/2023]

EPI (2020). Trends in the diversity of teachers in England [online article]. Retrieved from https://epi.org.uk/publications-and-research/diversity-of-teachers/ [accessed 28/04/2023]

Furlong, J. & Salisbury, J. (2005). Best practice research scholarships: An evaluation. *Research Papers in Education*, 20(1), 45-83. https://doi.org/10.1080/0267152052000341336

Guba, E. G. (1990). The Alternative Paradigm Dialogue. In E. G. Guba (Ed.), *The Paradigm Dialogue*. London: SAGE Publications Ltd.

Herbert-Smith, K. (2022). 6 ways to encourage teachers to become researchers [blogpost]. I*ris Connect Blog*. Available at https://blog.irisconnect.com/uk/6-ways-to-encourage-teachers-to-become-researchers [accessed 28/04/2023]

Impetus (2023). Education Endowment Foundation [webpage]. Available at https://www.impetus.org.uk/education-endowment-foundation#:~:text=The%20Education%20Endowment%20Foundation%20(EEF,What%20Works%20Centre%20for%20Education. [accessed 28/04/2023]

Lumivero (2020). NVivo (Version 14). www.lumivero.com

McLain, M., Schillaci-Rowland, D., Stables, K., Hardy, A. & Ryan, T. (2022). Researching Design and Technology Education: Educators Views and Experience. Proceedings for the 39th Pupils' Attitudes Towards Technology (PATT39) Conference, Memorial University, Newfoundland, 21-24 June, pp.205-212. www.pattontheedge.ca/proceedings

Maslow, A. H. (1943). A theory of human motivation. Psychological Review, 50(4), 370-396. https://doi.org/10.1037/h0054346

Maslow, A. H. (1954). Motivation and personality. New York: Harper and Row.

Ofsted (2022). *Education Inspection Framework* [webpage] Available at https://www.gov.uk/government/publications/education-inspection-framework/education-inspection-framework

Ofsted (2020). *Why we do research at Ofsted: Daniel Muijs (Ofsted's Deputy Director, Research and Evaluation from 2019 to 2021) summarises our reasons for carrying out our own research at Ofsted* [online]. Available at https://www.gov.uk/government/news/why-we-do-research-at-ofsted [accessed 28/04/2023]

Perry, T. (2022). What we don't yet know about cognitive science in the classroom. *Impact*. https://my.chartered.college/impact_article/what-we-dont-yet-know-about-cognitive-science-in-the-classroom/

Perry, T., Lea, R., Jørgensen, C. R., Cordingley, P., Shapiro, K., & Youdell, D. (2021). *Cognitive Science in the Classroom*. London: Education Endowment Foundation (EEF). Available at https://educationendowmentfoundation.org.uk/evidence-summaries/evidencereviews/cognitive-science-approaches-in-the-classroom/

Rudduck, J. & Hopkins, D. (1985). *Research as a Basis for Teaching: readings from the work of Lawrence Stenhouse*. London: Heinemann.

Ryan, R.M. & Deci, E.L. (2017). *Self-Determination Theory: Basic Psychological Needs in Motivation, Development, and Wellness*. London: The Guilford Press.

Skogh, I-B & de Vries, M.J. (2013). *Technology teachers as researchers: Philosophical and Empirical Technology Education Studies in the Swedish TUFF Research School*. Rotterdam: Sense Publishers.

Stremmel, A.J. (2007). The Value of Teacher Research: Nurturing Professional and Personal Growth through Inquiry. *Voices of Practitioners*, 2(3).

Stenhouse, L (1975). *An Introduction to Curriculum Research and Development*. London: Heinemann.

Design and Technology Education: An International Journal

28.2

# What do teachers of D&T think are the reasons for the decline of the subject in England?

**Claire Vickery, Doctoral Candidate, Nottingham Trent University, UK**
**Alison Hardy, Nottingham Trent University, UK**

## Abstract
This article discusses one part of the data from a larger research project that sought to identify factors that secondary school teachers of design and technology (D&T) in England felt may have contributed to the decline in entries at GCSE level within the subject. This study was designed to ensure the teacher's voice could be heard. Research was conducted in two parts, interviews and focus groups followed by an online survey, the first part provided qualitative and the second quantitative data. Questions within the online survey were informed by the qualitative data collection of part one. This article focuses on the findings from a specific question within part two of this data - the online survey. The factors indicated by the teachers within the survey are discussed in the findings section of this paper. The teachers' responses were organised into four categories: (1) macro level - external, national influences; (2) meso – school level; (3) micro – classroom influences, and (4) nano – individual level. Analysis of the teachers' responses indicated that the most noteworthy factor was the English Baccalaureate (EBacc), a government-imposed performance measure and influences from parents, the first at the macro level the second on the nano level. The least noteworthy factor was that more suitable examinations were available for upper secondary school pupils. It is hoped that this research will prompt professional dialogue regarding the decline of D&T entries at a macro, meso, micro and nano level and that subsequent action can be considered. Although conducted within England, this research prompts critical thinking that may help review educational practice internationally.

## Keywords
Design and Technology, Teacher Preparation, Continued Professional Development, Decline, England

## Introduction
The total number of entries into the Design and Technology (D&T) GCSE[i] within England has continuously declined since 2003. There is an exception in 2014 when there was a marginal increase in entries (JCQ, 2021a). Figure 1 shows that D&T has had the most significant decline in entries compared to other subjects, despite a rise in the total number of entries for all full GCSE courses.

As a teacher and head of D&T in a secondary school, this data confirmed the lead author's experience within their school that there was a decline of entries to the GCSE in the subject. Consequently, she decided to embark on this research project to understand the reasons for this decline.

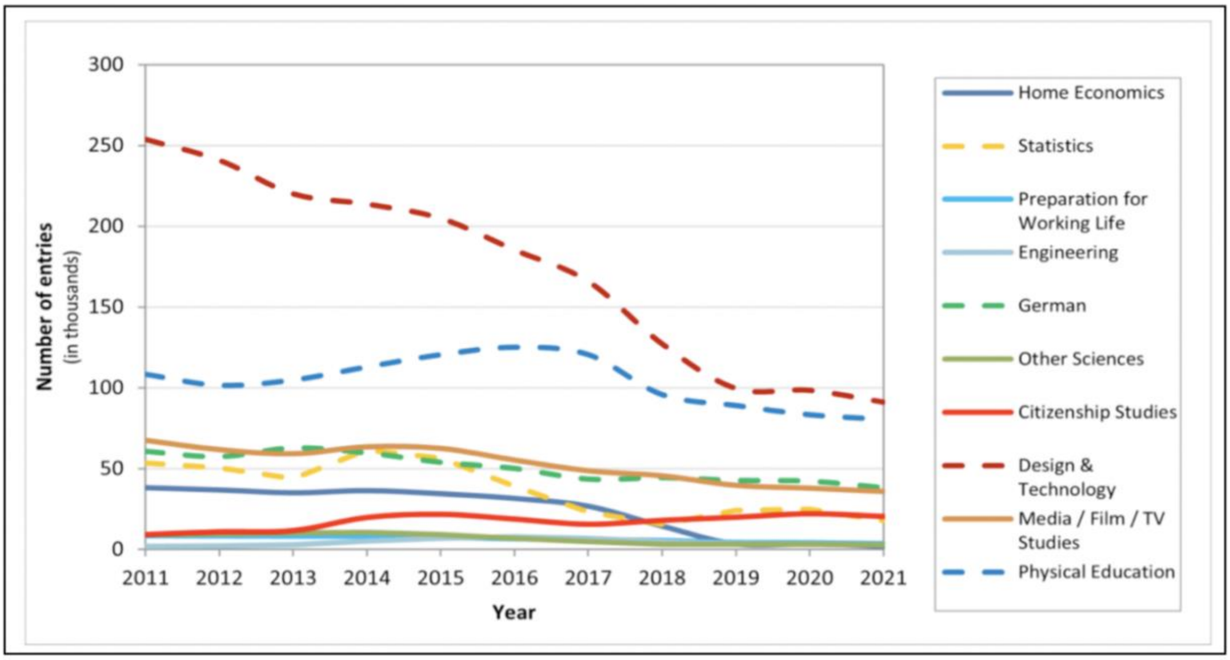



***Figure 1 GCSE courses with a decrease in entries (JCQ CIC, 2021b)***

## Literature Review

A review of relevant literature was undertaken to identify previously discussed factors that may have led to the decline in GCSE entries of D&T. Two papers were seen as key: Miller (2011) *What's wrong with D&T?* and McGimpsey (2011) *A Review of Literature on Design Education in the National Curriculum.* Both papers were commissioned by the Royal Society of Arts (RSA). In paper one, Miller reflects upon his personal and professional experiences as a student and later as a lecturer. In the second paper, McGimpsey (2011, p.1) reviews literature to "understand the development and current state of design and technology". Between them, Miller and McGimpsey discuss several factors that may have contributed to a poor perception of D&T. They suggest that a poor perception of D&T has led to the subject's omission from the English Baccalaureate (EBacc)[ii] and anticipated that D&T would be further marginalised by its omission from the EBacc. Whilst this paper acknowledges that the EBacc may have encouraged D&T's further decline the data discussed in the introduction confirms that the EBacc cannot be regarded as the sole cause. Although, Miller and McGimpsey's papers do not aim to discuss the decline in D&T GCSE entries directly, it was decided that their analysis of D&T, although in 2011, was a useful frame for this study.

The factors that were identified during the search for literature are considered on a macro, meso, micro and nano basis. The definition of each is explained in turn.

### Macro

Macro factors refer to external influences at national level, including government policies, advice from associations (e.g., the Design and Technology Association and Royal Academy of Engineers), and regulations set by examination bodies. The EBacc is an example of a factor at macro level.

In 2011, both Miller and McGimpsey suggested that the removal of D&T as a compulsory subject led to the decline in status of D&T. McGimpsey also suggests that the inclusion of technology in the STEM acronym, but no inclusion of design has led to a poor perception of the subject, with technology seen as being of greater importance than design.

Miller (2011) argues that the poor perception of the subject partly lies at macro level. He argues that D&T had an excellent opportunity when it was first introduced to the national curriculum in England, however the subject failed to achieve success. He claims that a reason for this are the perceptions of people outside the classroom, for example designers, policy writers and higher education academics such as himself. Miller's view is that these people take a view of D&T based on their understanding of what happens in the classroom. For example, when reflecting on his experience as a higher education admissions tutor: "In interviewing applicants for design courses, I have struggled to see the individual student emerge from the portfolio of DT [sic] project work-by numbers" (Miller, 2011, p. 7). Despite implying that the issue lies not with the macro level but with what is happening in the classroom, our view is that Miller is arguing that it is how those who have influence at the macro level, perceive what is happening in classrooms that shaped the development of D&T.

Miller also concedes that the vast curriculum is problematic. Reflecting on this, Stables (2012) wonders if the curriculum is prioritising the right things. In 2011, Miller suggested that the subject is too focused on technical content and manufacturing techniques, implying that he perceived these was an imbalance in the curriculum away from creativity. Analysis of the most recent English National Curriculum (Gov, 2013) shows that the word 'design' appears more often than the word 'technology'. This suggests that this is how the National Curriculum is interpreted by school D&T departments, with more focus on technical content and manufacturing techniques than the National Curriculum content details. Fahram et al (2018) describe how teachers tend to spend less time on content that they themselves have not mastered, which could account for the differences in curriculum within different settings.

Miller suggests that there is a lack of professional design experience and training amongst teachers, which means the design element of D&T has been neglected, and a lack of support was identified during the introduction of the subject (National Curriculum Council,1992). Although Jones et al (2019) identified that D&T teachers are more likely to have a Bachelor of Arts (BA) degree, rather than a Bachelor of Science (BSc). Taking a broad view of the differences between these two types of degree, this undermines Miller's view, but it cannot be assumed that an BA includes a greater focus on design than a BSc. Jones et al. (2019) found that teachers who held an arts background, rather than a technology background, lacked a broad understanding of technology and were unaware of their own deficiencies. This contrasts with Irving-Bell (2022) who found that teachers were aware of gaps within their subject knowledge, but she noted that a consequence of this awareness led to self-sabotaging behaviors such as anxiety and low self-esteem. With only 82.5% of teachers within the subject holding a post A-Level qualification relevant to D&T as a subject specialism (National Statistics, 2020a), a lack of specialists could be considered as an additional factor contributing to the decline of D&T.

Recruitment for teachers specialising in D&T at secondary education has been an issue for some time (Klassen et al., 2021). Despite a surge in applications for teacher training following the COVID-19 pandemic, recruitment is expected to remain challenging (Worth and Faulkner-

Ellis, 2021). In 2020, only 75% of the recruitment target for trainees within the subject was reached (National Statistics, 2020b). This was despite D&T being the only subject to have had their recruitment target decreased by 10%, after failing to achieve previous recruitment targets. Recruitment for beginner teachers within England is struggling and despite bursaries for trainees within the subject, only 25% of the recruitment target was met within England during the 2022/2023 academic year (Gov.uk, 2023a). Within England during the academic year 2022-2023, D&T was taught for 71.3% of the hours by teachers who did not hold a relevant post A-level within the subject (Gov.uk, 2023b).

McFarlane (2021) proposes that the struggle to recruit specialist D&T teachers can be attributed to the diversity of the subject. In other words, the range of materials, processes, and techniques a D&T teacher might have to teach, some of which may be beyond their previous learning from their school and university education.

Macro decisions have implications for decisions made at school level, which are discussed in the next section.

**Meso**

Both Miller (2011) and McGimpsey (2011) anticipated that a consequence of D&T's omission from the EBacc would be a reduction in the time and resources allocated to the subject within a school – the meso level. From our experience this consequence is still relevant, with teaching time reduced for D&T to give more time to the teaching of the Ebacc subjects. The significance of the EBacc as a performance measure for schools may have an impact on the qualifications offered to pupils aged 14-16 years old (those in upper secondary school). Using a case-study approach, Abrahams (2018) found that the subjects offered to pupils were done so strategically. Hardy's (2015) analysis of why the number of pupils studying GCSE has declined suggests that a school leader may fail to offer D&T to pupils if the subject has historically performed less well than other subjects. By offering higher performing subjects, the school are more likely to rank higher in national league tables, which are used to hold schools accountable (Lilliedahl, 2023).

Gaotlhobogwe (2012) found that pupils will enjoy D&T less and their achievement will suffer, if time, resources, and funding are cut. This could lead to a poorer perception of D&T, as the pupils will not feel as fulfilled by the subject and are likely to also voice these opinions to others, such as their parents. This could have an adverse effect on the subject's reputation.

Miller suggests that D&T departments can be isolated within the school because of the specialist classrooms that D&T require. Hardy (2021) argues that decisions made relating to the location and presentation of D&T can present implicit messages about the value of the subject. For example, D&T rooms are often at the back of the school for practical, logistical reasons but this means they are hidden away. Other examples include the images used to portray D&T (see the pictures used within Miller's paper, e.g., hands saws and frying pans), the clothes teachers wear (white lab coats and aprons) and requesting monetary contributions from parents.

Returning to the issue of time and resources, an ongoing challenge has been teaching pupils the full content of the national curriculum with limited time and resources. Since its inception, many schools organise the teaching of D&T as a series of rotations between material areas (e.g., six weeks designing and making with textiles, then moving onto plastics, electronics and so on). However, this structure restricts teachers from providing a progressively challenging curriculum and leads to a repertoire of low quality of skills and knowledge across various materials (Davies and Steeg, 2005; Choulerton, 2016). This style of curriculum organisation may influence how pupils and parents perceive D&T.

**Micro**

Micro factors refer to influences at classroom level. Miller’s (2011) perception of the school context is based on his experiences of working with pre- and in-service teachers, plus qualitative data collected from young people interested in D&T. He focuses on three aspects at the micro level: what is taught, how it is taught, and who it is taught by. Miller's analysis of how the subject is taught within the classroom is the most extensive, suggesting that he perceives the subject as most significantly impacted on a micro level.

The teacher is the most important factor within the classroom (Hattie, 2003) and is key in shaping how the subject is taught and received (Hardy 2015). Similarly, Wooff (2017) claims that the implementation of D&T continues to be influenced by individual interpretation of teachers, which may impact how the subject is structured and delivered within classrooms. Miller (2011) suggests that the subject is taught with a formulaic structure, which limits the creative input of pupils, something which has been previously reported in the early years of the D&T National Curriculum by McCormick, Murphy and Davidson (1994) and McCormick and Davidson (1996). Such structure discourages deep thought, reflection, and analysis (Williams 2000).

In 2008 and 2011, Ofsted reported on D&T identifying, amongst other issues, that not all D&T teachers have updated their subject knowledge, plus many lack expertise across material areas. Consequently, limiting pupil experience within the classroom. McGimpsey (2011) suggested that the diverse demands of subject knowledge are challenging for a single D&T teacher to meet within their curriculum (for example, rather than being an expert in a single material D&T teachers might be expected to teach across two or more material areas). This is like Miller’s view that the diverse curriculum affects recruitment at a macro level, whereas here McGimpsey’s focus, like Ofsted’s, is on what is happening in the classroom. This is an example of where a macro decision – that is the National Curriculum content, influences more than one level.

However, it must be noted that Davies (2022) refutes the claims from Miller (2011) and McGimpsey (2011) that teachers are to blame for the failure of the subject and concludes that the situation is more complex than the factors on the micro level.

**Nano**

Finally, the nano level, where factors are influenced by individual choices or action. Here we focus on pupils and their parents. As noted above, how a teacher interprets a curriculum may differ from what is intended. Similarly, pupils may perceive what is taught in unintended ways (Maw, 1993). Pupils’ engagement with a subject can be influenced by how meaningful it is to them (Priniski, Hecht & Harackiewicz 2018). If their teacher’s interpretation of D&T does not align with the views of the pupils, then this may affect their engagement and achievement in D&T (Hardy 2017).

This returns us to the hidden curriculum which was discussed within the meso section of this literature review. We can apply this theory here and consider that it is because such unintended symbolism may be perceived in different ways and may influence pupil perceptions, either consciously or subconsciously, of what constitutes as social norms within the subject. Notably, the notion of a hidden curriculum has been considered as a reason for a perceived gender divide within the subject (Sultan et al., 2018; OECD, 2015; Harding, 2009).

According to Miller (2011), pupils perceive subject content as hard and felt that the examination coursework required a large volume of work. In addition, McGimpsey (2011) identified that the subject is not favoured by high-attaining students. This is contrasts with the findings of Bell et al. (2015) who collected data from pupils aged 11-14, and found pupils thought D&T was too easy and felt that pupils did not need to be clever to study this subject. Either of these views will affect whether a pupil, and their parent, view D&T as a suitable post-14 subject to study that leads to a qualification (Eccles & Wigfield, 2002).

**Literature Review Conclusions.**

Decisions made at macro level, in practice influences decisions made at school level, classroom level and on an individual level. For example, on school level subject allocation, such as the number of hours taught and the number of teachers within a subject may be affected. At classroom level, the core knowledge that is taught may be changed and at nano level the perception of the subject may be influenced by an omission. It is worth noting that since the initial literature review, further items have been published which discuss the decline of D&T (e.g., Spendlove, 2022) and the future of D&T education (Pearson, 2023; Halliwell et al, 2023; Design and Technology Association, 2023).

## Research Question

This paper aims to answer this question:

- How has the decline in D&T been impacted by decisions made at a national, local, classroom and individual level?

Within this research, these four levels are described as (1) macro - national governance level; (2) meso refers to the subject at a school level; (3) micro - classroom level and (4) nano refers to an individual, such as the pupil or their parents.

## Methodology

Following the literature review, research was conducted to investigate the opinions of teachers. This study was designed to ensure the teacher's voice could be heard. Participants provided valuable insights into their experiences as a teacher of D&T and their journey to becoming one. An interpretative approach was undertaken throughout this research. It is important to note that an interpretative approach does not claim to provide a definitive answer to the research questions, as one will never be able to fully understand the experiences of another (Palmer, 1969). Instead, an interpretive approach is based on the author's interpretation of the participants' lived experiences data analysis (Dibley et al., 2020). For this study, that meant the authors interpreted the D&T teachers' responses to help mitigate against a further decline of D&T.

This article discusses one part of the data from a larger research project, that sought to identify factors that secondary school teachers of design and technology (D&T) in England felt may have contributed to the decline in entries at GCSE level within the subject. For the larger study, several methods of participation were offered to encourage the involvement of teachers who often feel that their workload is excessive (Jerrim et al., 2021). Data collection included an online survey, asynchronous focus group, synchronous focus group and semi-structured interviews, which ran concurrently. Such data collection methods enabled data to be triangulated to strengthen the validity of the research. Participants could opt for the data collection with which they felt most comfortable. Data was collected iteratively and analysed, through coding, in to guide subsequent data collection. Quantitative approaches were utilised within the online survey, which could support or contrast the qualitative data collected through the asynchronous forum, synchronous focus group and semi-structured interviews.

**Research Methods**

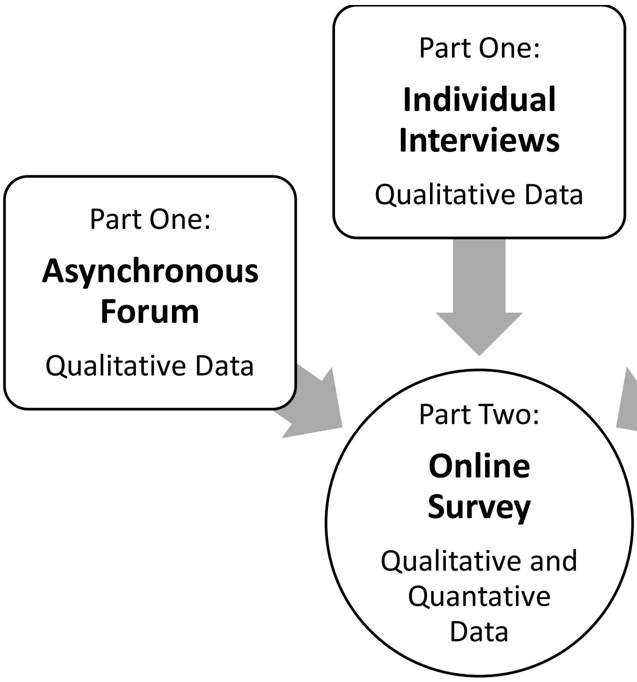



***Figure 2: Methods of data collection***

This study collected data in two parts. Only qualitative data was collected in Part One. This data was used to inform the creation of an online survey, which was used as the tool for data collection in Part Two. During Part Two, both quantitative and qualitative data were collected. A mixed method of data collection was used for the following reasons:

- To ensure teachers could contribute to the study in their preferred way.
- To provide further breadth and depth to the data than may have been possible by using just one method of data generation (Bello, 2021).
- To ensure a rigorous study was undertaken, methodological triangulation was used (Flick, 2018). This was important, as the nature of the data that was collected is

subjective, and therefore individually the reliability and validity of this data can be questioned (Burns, 2000).

**Recruitment**

The recruitment of participants was essential to the validity of the project. Recruitment was largely undertaken through social media to align with the data collection planned to be conducted virtually. Posts were made on several D&T community Facebook groups. During this phase of the project, it was identified that particular age groups participate within social media platforms in differing ways (Brandtzaeg and Chaparro Dominguez, 2018); in other words, if participants were only recruited via Facebook there was likely to be a narrow age range of teachers who responded. Therefore, to overcome this, 'snowballing' was encouraged (Gibson, 2017). Fifty schools selected at random, were sent invitations through the post. However, this had no effect, and it is noted that all participants have been recruited via social media which potentially limits the types of teachers participating within the project.

**Initial Sampling**

Participants were required to be:

- a qualified teacher
- having taught D&T in a secondary school for at least one full academic year within England since September 2020, on either a part-time or full-time basis.

Consideration was given to focusing upon teachers from within specific material specialism. However, at this stage this was deemed restrictive, potentially weakening the data collection, and not allowing the data to portray the diversity of thought that could be uncovered amongst teachers of contrasting material areas. Participant consent was gained through an online form, and participants were asked to confirm that they met the sampling criteria. Except where doubts were held during the data collection, no further checks were made to clarify the credentials of individuals. Where checks were made, and individuals were not found to meet the initial sampling criterion the data they contributed was withdrawn from the analysis.

**Data Generation**

In line with the iterative approach that was at the heart of the research project, an openness was maintained, that was responsive to the constant generation and analysis of data and allowed flexibility to act upon new or unexpected lines of enquiry. A decision was made to collect all data virtually, such as through video calls and written word. Conducted during a time of uncertainty, this ensured that data collection could continue despite COVID-19 restrictions that may have been unexpectedly enforced. Equally, an advantage of collecting data this way, was that it allowed participation from teachers who were located within different areas of England or located elsewhere (assuming they fulfilled the initial criterion). As the research was conducted online, it was important to reduce technical issues, which would have had a negative impact upon the generation of data and could have led to disengagement amongst participants. A private Facebook group was used as the platform for the asynchronous focus group,' Zoom' was used for the semi-structured and synchronous focus group, and 'Survey King' was used for the online survey. These platforms were chosen due to their perceived reliability and the functions that they offered. It was important to ensure that the platforms could be accessed using a variety of devices, including smartphones, which are the most used device to access the internet (O'Dea, 2020).

The next section describes part one and part two of the data collection.

**Part One: Asynchronous Forum, Individual Interviews and Focus Group**

The role of the teacher is central to the subject and except for students themselves, teachers have the highest impact on pupil progress amongst other influences such as their home, peers and the school they attend (Hattie, 2003). Yet, within the literature review their voice on 'the decline within D&T' was missing. Several methods of participation were offered to encourage the involvement of teachers, who often feel that their workload is excessive (Jerrim et al., 2021). The first method of data collection was an asynchronous forum, which was hosted on a private 'Facebook' group. Social media offers a platform that enables interactions with others that fits into the participants' busy lives (Dhanalakshmi et al., 2017). Participants could self-manage how much time they spent participating in the group and when they participated. Williams et al. (2012) claim that 'asynchronous' platforms often see participant responses that are more carefully considered and reflective than traditional synchronous focus groups. Two additional methods of data collection were used in part one, as it was acknowledged that without face-to-face contact, participants are more likely to withdraw from research (Reips, 2000). Semi-structured interviews and a synchronous focus group were held virtually as video calls.

**Part One: Participants**

Table 1 shows the number of participants within each method of data collection during part one. Some participants took part in more than one method.

***Table 1: Part One Participants***

| | Asynchronous Forum | Individual Interviews | Focus Group |
|---|---|---|---|
| Number of participants | 21 | 7 | 3 |

**Part One: Findings**

The data from Part One was used to inform the Part Two data collection. Twenty-six factors for the decline in entries were identified.

**Part Two Data Collection**

Part Two of the data collection was an online survey, which was informed by the data collection of Part One. The survey was divided into five sections:

1. About you (Your current role, previous experience, and teacher training).
2. Your thoughts, feelings, and perspectives about D&T.
3. Key Stage 3 curriculum (lower secondary school, pupils aged 11-14 years old)
4. Key Stage 4 curriculum (upper secondary school, pupils aged 14-16 years old, where pupils typically study for General Certificate of Education (GCSE) qualifications.
5. Continued Professional Development

In this paper, we are reporting on one question from the second section: 'Your thoughts, feelings, and perspectives about D&T′: "Reflecting on your experiences, which of the following factors do you feel have impacted on the decline in entries to GCSE D&T?" Participants were able to select as many factors as they felt appropriate.

**Part Two – Participants**

Twelve respondents to the survey met the sampling criteria and were included in the final data set. Eight of these respondents were the Head of the D&T department within their setting and four were classroom teachers. All had been teaching for at least seven years, six had been teaching for more than 15 years. Except one participant, all had completed their initial teaching training in D&T; the exception was trained as an art and design teacher.

***Table 2: Part Two Participants***

| | |
|---|---|
| Number of participants | 12 |
| Note | some members may have also participated within the data collection of part one. |

In the next section, the findings are shown and analysed. This is then followed by a discussion.

## Findings and analysis

The first step involved categorising the factors into the levels (Columns macro, meso, micro and nano in Table 3). Using the literature review and our analysis of the 26 factors, eighteen factors were categorised as influencing at only one level, four at two levels, two at three levels and two at all four levels (Historic/Outdated perceptions of what D&T is or should be). Thirteen factors were categorised macro, eleven meso, eight micro and eight nano. Factors identified from Part One, were where teachers gave qualitive responses to the question 'What do you think impacted on the decline of D&T?'. It's interesting to note that of the 26 factors, most were categorised as being outside the participants' direct control – those at the macro level, whilst the next most common category, the meso level, is where teachers have some control and influence. We acknowledge that this categorisation is subjective, and others may apply the levels differently.

The next step involved analysing the responses against each factor by the total number of participants (see the last three columns and the row 'Total number of responses for each level' in Table 3 and all of Table 4). The Ebacc and influence from parents were the most selected factors (n=8). No factor was selected by all the participants (Table 4), but this might be due to the small sample size and the large list of factors, so the likelihood of agreement diminishes. Four factors were only selected by one participant:

1. Belief that the GCSE is too hard (nano).
2. Primary school experiences of D&T (meso and micro).
3. Disparity in how D&T is taught (meso and micro).
4. Gender bias (micro and nano).

The order of the total number of responses for each level matches the order of the number of factors for each level: macro, meso, micro and nano. This implies that the macro and meso factors were seen as having a greater influence on the decline of D&T GCSE numbers than the micro and nano. This is explored in the Discussion.

Finally, the data was analysed and compared by the teachers' role: head of department and class teacher. All four teachers selected two factors: Ebacc and lack of funding. The heads of department did not all agree on any single factor (Table 4); the most common factor was influence from parents. There was one factor the teachers did not select, that was selected by the heads of department: belief that D&T GCSE is too hard. This compares with four factors not selected by the heads of department but selected by the teachers:

1. Too many/or unsupported changes to the subject (macro).
2. Primary experiences within D&T (meso)
3. Disparity in how D&T is taught (meso and micro)
4. Gender Bias (micro and nano).

There appears to be no pattern between the levels of these four factors. It might be that because most of the participants were heads of department, who as part of their role interact more with school leaders and managers that they are more aware of these factors. It is difficult to make any meaningful comparison between the responses by the two groups (head of department and classroom teacher) because the sample size is small (n=8; n=4). However, it can be commented on where there is a noticeable disparity or similarity.

More of the teachers (75%) selected lack of support from official bodies (macro) than the heads of department (12.5%). This disparity was the same for five other factors (see Table 3). There was no disparity in reverse for any factor; in other words, there were no noticeably higher percentage of the heads of department selecting a factor compared to the teachers.

Ten factors were selected once by both groups (Table 4), suggesting a lack of consensus amongst the participants, which is unsurprising given the number of factors listed in the survey compared to the sample size.

***Table 3 Factors, levels, and responses to the survey***

| Factor | Macro (Gov) | Meso (School) | Micro (Classroom) | Nano (Individuals) | Teachers (n=4) | Heads of department (n=8) | Total (n=12) |
|---|---|---|---|---|---|---|---|
| EBacc | | | | | 4 | 4 | 8 |
| National Curriculum is ill-fitting | | | | | 2 | 2 | 4 |
| Lack of support and engagement from official bodies | | | | | 3 | 1 | 4 |
| Lack of requirement of D&T GCSE at further/higher education | | | | | 2 | 2 | 4 |
| GCSE specification is too broad or too narrow | | | | | 1 | 2 | 3 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Too many/or unsupported changes to the subject | | | | | 2 | 0 | 2 |
| Suitability of GCSE specification for 14–16-year-olds | | | | | 1 | 1 | 2 |
| Maths and science content with GCSE specification | | | | | 1 | 1 | 2 |
| Post-14 option blocks | | | | | 3 | 4 | 7 |
| Lack of lower secondary teaching time | | | | | 3 | 1 | 4 |
| Timetabling | | | | | 1 | 2 | 3 |
| Influence from other school staff | | | | | 2 | 2 | 4 |
| Resistance to change from D&T teachers | | | | | 1 | 1 | 2 |
| Primary experiences within D&T | | | | | 1 | 0 | 1 |
| Influence from parents | | | | | 3 | 5 | 8 |
| Belief that the D&T GCSE is too easy | | | | | 3 | 1 | 4 |
| Peer pressure to choose other subjects | | | | | 1 | 2 | 3 |
| Belief that the D&T GCSE is too hard | | | | | 0 | 1 | 1 |
| Lack of funding/tools and equipment | | | | | 4 | 1 | 5 |
| Lower secondary experiences within D&T | | | | | 3 | 3 | 6 |
| Disparity between teachers in the way D&T is delivered within settings | | | | | 1 | 0 | 1 |
| Lack of skilled teachers | | | | | 3 | 2 | 5 |
| Disparity between teachers in the perception of what D&T is or should be | | | | | 3 | 1 | 4 |
| Gender Bias | | | | | 1 | 0 | 1 |
| Amount of theory that is required to be studied | | | | | 1 | 3 | 4 |
| Historic/Outdated perceptions of what D&T is or should be | | | | | 3 | 1 | 4 |
| Count of factors per level | 13 | 11 | 8 | 7 | | | |
| Total number of responses for each level | 51 | 47 | 27 | 26 | | | |
| Average | | | | | 2.0 | 1.7 | 3.7 |

***Table 4 Count of the factors selected.***

| Number of factors | Teachers | Heads of department | Total |
|---|---|---|---|
| 0 | 1 | 4 | 0 |
| 1 | 10 | 10 | 4 |
| 2 | 4 | 7 | 4 |
| 3 | 9 | 2 | 3 |
| 4 | 2 | 2 | 9 |
| 5 | N/A | 1 | 2 |
| 6 | N/A | 0 | 1 |
| 7 | N/A | 0 | 1 |
| 8 | N/A | 0 | 2 |

## Discussion

In this section we discussed how our data analysis compares with the factors identified in the literature. Within each sub-section we explored why some factors seem to rank higher than others in the participants' perception, as impacting on the decline of D&T.

It should be remembered at this point that the survey's 26 factors came from analysis of the data in Part One; so some factors mentioned in the literature are excluded because they were not listed in the survey. Therefore, we cannot assume that there is an issue if a factor is mentioned in the literature but not in the data for Part Two.

The notable factors omitted from the survey included imbalance of curriculum content (technical versus design) (Miller, 2011), teacher recruitment (Klassen et al., 2021; McFarlane, 2021), professional development and training (Miller, 2021), and the formulaic structure of design activity (McCormick, Murphy and Davidson, 1994; McCormick and Davidson, 1996; Miller, 2011).

### Macro

The Ebacc was the most selected factor in our data, as was mentioned specifically by both McGimpsey and Miller (2011). However, in our study the participants did not go back to 2004 when D&T was removed as a compulsory subject, as it was not included as a factor from the data analysis of Part One. Both our data and the Literature comments on the curriculum content as a factor in the subject's decline. Although, the brevity of the factor in the survey means it is difficult to state that the concerns are similar. The literature focuses on the National Curriculum whilst the survey asks about the GCSE content and whether the National Curriculum was ill-fitting.

Whilst teacher recruitment and professional development were not explicit in the survey's factors, they are hinted at in four factors: (1) too many or unsupported changes to the subject; (2) disparity between teachers in the perception of what D&T is or should be; (3) Lack of skilled teachers, and (4) disparity between teachers in the way D&T is delivered within settings. There was also the idea that there is little or no direction from national bodies about how to adapt current practices to new curriculum content.  This lack leads to differences in classrooms and within departments that cause confusion for the pupils and conflict amongst colleagues. Neither outcome produces a positive perception of D&T, instead it leaves outsiders, like pupils, parents, and school senior leaders even more confused about the purpose and value of D&T.

It was suggested that Miller's (2011) view, that the poor perception of the subject by more distant outsiders (for example, higher education design lecturers), was the reason for the participants' view that the lack of requirement of D&T GCSE for further or higher education courses undermined the status of the subject.

### Meso

At the school level, the reduction in teaching time and resources were factors in our data but they were less so, than the impact of whether the subject is made available for pupils to study post-14 (Hardy 2015, Abrahams, 2018). In our survey, the factor was specifically about pre-14 teaching time, whereas in the Literature Review the focus is on post-14 time. Anecdotally, we know of several schools where teaching time for D&T is reduced in Key Stage 3 (11-14 year-olds) due to teacher recruitment, funding and increasing time given for English and mathematics. It seems obvious to say this, but it will have an implication on the number of pupils studying GCSE D&T (the focus of our research question). Particularly if teachers feel there is too much subject content to be covered in the time available, resulting in pupils not being prepared for post-14 study, as they have had insufficient time in the first three years of secondary school. We have noticed that more teaching time is now spent on 'theory' in D&T rather than on directly engaging in a design project, where pupils can actively develop their design capability (Stables 2012).

A new factor was the influence of other staff (i.e., non-D&T teachers or support staff). This suggests to us that this group have a poor or confused perception of D&T and struggle to encourage pupils to study D&T post-14.

**Micro**

Miller (2011) and Wooff (2017) identified teachers' individual interpretation of D&T as having an influence on its implementation which in turn impacts on pupils' engagement with the subject (Hardy 2017). This view is reflected in our analysis in a few factors, including 'resistance to change from D&T teachers' and disparities between teachers in how they teach and perceive the subject. Although, there are eight factors identified at this level and the literature talks about the impact the teacher has on pupils, the responses suggest that the participants do not see this level as where there is the greatest impact on the subject's decline.

This suggests the participants perceive they have less influence on the subject than national or local actions. We wondered if this was because teachers feel they have less agency over what they teach and how they teach it (Connolly and Hughes-Stanton, 2020), and so see fewer possibilities of control over the decline as existing within their classrooms.

**Nano**

Only one participant thought the perceived gender bias within D&T was a factor in the subject's decline, which may be seen as surprising given the extensive research conducted and reported on in this area (Sultan et al., 2018; OECD, 2015; Harding, 2009). However, this research tends to focus more on how females are excluded, often unintentionally, from the subject, not on the consequence of this exclusion on the status or nature of the subject.

Parents influence on pupils' choices and engagement was a significant factor for the participants but in our literature search was a more minor factor. We think this area warrants further research as it is deemed to be so significant to teachers, albeit a small sample.

## Conclusions

We set out to answer the question 'How has the decline in D&T been impacted by decisions made at a national, local, classroom and individual level?' with responses and perceptions from practicing D&T teachers. As we set out in the methodology section, this study was designed to ensure the teacher's voice could be heard. We used Miller's and McGimpsey's papers from 2011 to frame the literature review. We recognise these are dated sources, but it has been interesting to see how many of their observations resonate with the teachers' responses in our data. So, in answer to our question, our analysis has shown that, according to our participants, there are many factors impacting on D&T's decline. Most are at national and local level, which some teachers may see as being beyond their control or influence to rectify. Factors at a classroom and individual level were also identified but not as many as those at the national and local level. The most selected factors were the 'Ebacc' and 'parents' influence', notably these are at opposite ends of the spectrum outside of a teacher's sphere of control or influence. There were differences between the two groups of teachers who participated: classroom teachers and heads of department. Whilst both groups agreed about the Ebacc and parents' influence, the teachers also thought lack of funding was having a negative impact on D&T.

One recurring theme from the literature and our analysis is the need for professional development, not only for 'subject knowledge' but also for 'curriculum organisation' and 'debating the nature of the subject'. If teachers go through these three types of professional development, then we think this could have a positive effect on the perception of the subject. In the first case, teachers could experience new equipment and techniques within their subject area by completing industry-related experience, as the Design and Technology Association currently offers through their 'BluePrint1000' programme. In the second, supporting teachers in planning curriculum changes, using an action research model would give more confidence to others outside D&T, as they could see how the teachers have tried and evaluated their ideas following a set structure. This idea would build on Roberts' (2001) call to support teachers-as-researcher. Similarly, Halliwell et al. (2023) have recently reported on a D&T teacher-led project developing D&T curriculum ideas between teachers. These can happen more informally with local network groups or teachers who connect via social media. Davies (2022) identified this 'ground-up solution' in her work. Supporting this type of low-cost solution may encourage teachers to become inspired, learn new knowledge from each other to build a supportive, local community. Although low in financial cost, there could be cost to schools including release from lessons, however the return on this low investment could lead to retaining more knowledgeable teachers.

## Recommendations

We are not claiming that these three solutions would stop or reverse the decline of D&T, but they are solutions which address three of the four levels discussed in this paper. The fourth level (nano), with parent and pupils, is under-researched and we think future studies exploring the origins of parents' and pupils' views of D&T and how these influence their view of the subject would be useful. Eccles & Wigfield's (2002) expectancy-value theory, combined with Hardy's Subject Values Instrument for Design and Technology Education (SVA-D&T) (Hardy et al., 2022), could be a good starting point for such a study. We recognise that action needs to happen at each of the identified levels, as they are factors identified in this paper that have contributed to the subject's decline.

Further investigation into teachers' perceptions will contribute to the research on D&T education within England, which is currently limited. Although centered specifically upon teachers of D&T within England, it is hoped that the findings and recommendations from this research prompt professional dialogue and review to instigate change in education beyond this context. This research was designed to acknowledge the importance of the 'teacher' and reinforce that their voice must be listened to for positive changes to be made.

## Acknowledgements

We would like to thank Dr Richard Kimbell, who mentored Claire Vickery's PATT39 conference submission, the precursor to this paper, and Dr Sarah Davies, who has provided useful feedback on earlier iterations of this paper.

## References

Bell, D., Morrison-Love, D., Wooff, D. and McLain, M. (2017). STEM Education in the Twenty-First Century: Learning at Work – An Exploration of Design and Technology Teacher Perceptions and Practices. *International Journal of Technology and Design Education*, vol. 28, no. 3, pp. 721-737.

Bello, M, F. (2021) *Triangulation in Social Research: Mixing Qualitative and Quantitative Approaches* Burlington, Society Publishing.

Brandtzaeg, P.B. and Chaparro Dominguez, M. A. (2018). A Gap in Networked Publics? A Comparison of Younger and Older Journalists. *Nordicom Review*, vol. 39, no. 1, pp. 95-109 [Online]. DOI:10.2478/nor-2018-0004 (Accessed: 18 July 2021).

Burns, R, B. (2000). *Introduction to Research Methods*, 4th ed, London, SAGE Publications Ltd.

Choulerton, D. (2016). *Are we getting it right? Design and technology from primary to GCSE.* Retrieved 07/22 2016, Retrieved from http://www.slideshare.net/Ofstednews/datasummerschoolkeynote2016

Connolly, M., & Hughes-Stanton, J. (2020). The professional role and identity of teachers in the private and state education sectors. *British Journal of Sociology of Education*, *41*(5), 717-732.

Department for Education. (2019). *English Baccalaureate (Ebac)* [Online]. Retrieved 7 November 2023 from https://www.gov.uk/government/publications/english-baccalaureate-Ebac/english-baccalaureate-Ebac

Design and Technology Association. (2023). *Reimagining D&T* [Online]. Retrieved from https://www.designtechnology.org.uk/media/4843/reimagining-dt-our-vision-v9.pdf

Dhanalakshmi, N. and Subramanian, V. M. (2017). New Communication Styles in Social Media. *Language in India*, vol. 17, no. 7, pp. 427-438. [Online] Retrieved 13 August 2021 from http://www.languageinindia.com/july2017/dhanalakshmisocialmedialanguage1.pdf

Dibley, L., Dickerson, S. and Vandermause, R. (2020). *Doing Hermeneutic Phenomenological Research,* London, SAGE Publications Ltd.

Eccles, J. S., & Wigfield, A. (2020). From expectancy-value theory to situated expectancy-value theory: A developmental, social cognitive, and sociocultural perspective on motivation. *Contemporary Educational Psychology, 61*, 101859. Retrieved from https://doi.org/10.1016/j.cedpsych.2020.101859

Fahram, B., Norström, P. and Gumaelius, L. (2018). Changing Competencies, Changing Attitudes? How Teachers Become Technology Teachers', *36th International Pupils' Attitudes Towards Technology Conference.* Athlone Institute of Technology, Co. Westmeath, Ireland, 18–21st June 2018. Ireland, Technology Education Research Group.

Flick, U. (2018). 'Triangulation' in Denzin, N. K. and Lincoln, Y. S. (eds) *The SAGE Handbook of Qualitative Research*, 5th edn, London, SAGE Publications Ltd.

Gibson, L. (2016). 'Type Me Your Answer'. *Collecting qualitative data: A practical guide to textual, media and virtual techniques*, 213.

Halliwell, A., Mason, A., Hardy, A., & Ellis, C. (2023). A developing project: investigating future forms of design and technology education. *The 40th International Pupils' Attitudes*

*Towards Technology Conference Proceedings 2023*, *1*(October). Retrieved from https://openjournals.ljmu.ac.uk/PATT40/article/view/1627

Harding, J. (2009). Gender and Design and Technology Education, *Journal of Design & Technology Education,* vol. 2, no. 1, pp. 20-26 [Online]. Retrieved 10 April 2021 from https://ojs.lboro.ac.uk/JDTE/article/view/376

Hardy, A. (2015) *Why has the number of teenagers taking design and technology GCSE dropped?* [Online]. Retrieved 8 April 2021 from https://theconversation.com/why-has-the-number-of-teenagers-taking-design-and-technology-gcse-dropped-46361

Hardy, A. (2017). The consequence of school performance measures–inequality of access and opportunity. *Race Equality Teaching*, *34*(2), 39-43.

Hardy, A. (2021). Talking D&T 060: Ways of Thinking About D&T Curriculum, *Apple Podcasts* [Podcast]. 2 February 2021. Retrieved 6 February 2021 from https://podcasts.apple.com/gb/podcast/talking-d-t/id1460834167

Hardy, A., Dunn, A., & Morales-Verdejo, J. (2022). How do D&T teachers value design and technology education? n: D. Gill, J. Tuff, T. Kennedy, S. Pendergast and S. Jamil, eds., *PATT 39: PATT on the Edge: Technology, Innovation and Education, St. John's, Newfoundland and Labrador, Canada 21-24 June 2022. Proceedings.* Newfoundland: Faculty of Education, Memorial University of Newfoundland, pp. 38-48. ISBN 9780889015050

Hattie, J.A.C. (2003). Teachers make a difference: What is the research evidence? B*uilding Teacher Quality: What does the research tell us ACER Research Conference*, Melbourne, Australia, October 2003. Australian Council for Educational Research [Online] Retrieved 11 January 2022 from http://research.acer.edu.au/research_conference_2003/4/

Irving-Bell, D. (2022). Influence of teachers' perceptions of subject knowledge on pedagogical approaches. In *Debates in Design and Technology Education* (pp. 165-177). Routledge, London.

JCQ CIC. (2021a). Examination Results [Online] Retrieved from https://www.jcq.org.uk/examination-results/(Accessed 19 December 2021).

JCQ CIC. (2021b). GCSE, Project, and Entry Level Trends - UK, 2021. [Figure]. Retrieved 19 December 2021 from https://www.jcq.org.uk/wp-content/uploads/2021/08/GCSE-Projectand-Entry-Level-Trends-2021.pdf.

Jerrim, J., Sims, S. and Allen, R. (2021). *The Mental Health and Wellbeing of Teachers in England.* [Online] London, UCL and Institute of Education. Retrieved 14 December 2021 from http://repec.ioe.ac.uk/REPEc/pdf/qsswp2101r.pdf.

Jones, L., McDermott, H., Tyrer, J. and Zanker, N. (2019). The Effect of Teacher's Confidence on Technology and Engineering Curriculum Provision. *International Journal of Technology and Design Education,* vol. 31, no. 1, pp. 117-137 [Online]. Retrieved 8 February 2021 from https://link.springer.com/article/10.1007/s10798-019-09542-4>

Klassen, R., Rushby, J., Durksen, T. and Bardach, L. (2021). Examining Teacher Recruitment Strategies in England. *Journal of Education for Teaching*, vol. 47, no. 2, pp. 163-185 [Online]. Retrieved 13 March 2021 from https://www.tandfonline.com/doi/abs/10.1080/02607476.2021.1876501

Lilliedahl, J. (2021). Is there a Transnational Trend of "Nudging" Away from the Arts? How the Selection Device Works in the European–Swedish Context. *Arts Education Policy Review*, vol. 122, no. 2, pp.1-10 [Online]. Retrieved 3 April 2021 from https://doi.org/10.1080/10632913.2021.1903639

Maw, J. (1993). The National Curriculum Council and the Whole Curriculum: Reconstruction of a Discourse? *Curriculum Studies*, vol. 1, no. 1, pp. 55-74 [Online]. DOI: 10.1080/0965975930010104 (Accessed: 8 April 2021).
McCormick, R., Murphy, P., & Davidson, M. (1994). Design and technology as revelation and ritual. Retrieved from https://repository.lboro.ac.uk/articles/conference_contribution/Design_and_technology_as_revelation_and_ritual/9343823
McCormick, R., & Davidson, M. (1996). Problem solving and the tyranny of product outcomes. *Journal of Design & Technology Education, 1*(3).
McFarlane, C. (2021). We Must Ditch the Dusty View of Design and Technology, *Tes*, 18 April 2021 [Online]. Retrieved 19 April 2021 from https://www.tes.com/news/we-must-ditch-dusty-view-design-and-technology
McGimpsey, I. (2011). RSA Design & Society. A Review of Literature on Design Education in the National Curriculum [electronic document]. Retrieved 6 November 2023 from https://www.thersa.org/globalassets/pdfs/blogs/rsa_dt-lit_review_final.pdf
Miller (2011). *What's Wrong with DT?* [Online], London, RSA Design & Society. Retrieved 17 December 2021 from https://www.thersa.org/globalassets/pdfs/blogs/rsa_whats-wrong-with-dt.pdf
National Curriculum Council. (1992) *National Curriculum Technology: The Case for Revising the Order* [Online], London, National Curriculum Council. Retrieved 11 April 2021 from https://www.stem.org.uk/resources/elibrary/resource/27698/national-curriculum-technology-case-revising-order-1992
National Statistics. (2020a). *Reporting Year 2019: School Workforce in England* [Online]. Retrieved 29 March 2021 from https://explore-education-statistics.service.gov.uk/find-statistics/school-workforce-in-england
National Statistics. (2020b). *Academic Year 2020/21 : Initial Teacher Training Census* [Online]. Retrieved 10 April 2021 from https://explore-education-statistics.service.gov.uk/find-statistics/initial-teacher-training-census/2020-21
O'Dea, S. (2020). *Which is the Most Important Device you use to Connect to the Internet, at Home or Elsewhere?* [Online]. Retrieved 28 May 2021 from https://www.statista.com/statistics/387447/consumer-electronic-devices-byinternet-access-in-the-uk/
OECD, (2015). The ABC of Gender Equality in Education: Aptitude, Behaviour, Confidence [Online]. Pisa, OECD Publishing. Retrieved 26 March 2021 from https://www.oecd.org/pisa/keyfindings/pisa-2012-results-gender-eng.pdf
Ofsted. (2008). *Education for a Technologically Advanced Nation* [Online]. London, Crown Copyright. Retrieved 1 February 2021 from https://www.stem.org.uk/system/files/elibrary-resources/legacy_files_migrated/23374-Education%20for%20a%20Technologically%20Advanced%20nation.pdf
Ofsted. (2011) *Meeting Technological Challenges: School Design and Technology Provision* [Online]. Retrieved 2 February 2021 from https://www.gov.uk/government/publications/meeting-technological-challenges-school-design-and-technology-provision
Palmer, R. E. (1969) *Hermeneutics*, Evanston, Northwestern University Press.
Pearson. (2023, May 23,). The Future of Design Education. Retrieved July 10 2023, from https://www.pearson.com/uk/educators/schools/subject-area/extended-curriculum-and-btec/art-design-and-media/the-future-of-design-education.html

Priniski, S. J., Hecht, C. A., & Harackiewicz, J. M. (2018). Making Learning Personally Meaningful: A New Framework for Relevance Research. *The Journal of Experimental Education, 86*(1), 11-29. 10.1080/00220973.2017.1380589

Reips, U-D. (2000) 'The Web Experiment Method: Advantages, disadvantages, and solutions'. In M. H. Birnbaum (Ed.), *Psychological Experiments on the Internet*. San Diego, CA: Academic Press.

Spendlove, D. (2022). Why did design and technology education fail, and what might replace it? In A. Hardy (Ed.), Debates in Design and Technology Education (pp. 65-76). Routledge.

Stables, K. (2012). Designerly well-being: Can mainstream schooling offer a curriculum that provides a foundation for developing the lifelong design and technological capability of individuals and societies? Linkoping Electronic Conference Proceedings.

Sultan, U., Axell, C. and Hallström, J. (2018) 'Girls' engagement in technology education: A systematic review of the literature'. *36th International Pupils Attitudes Towards Technology Conference.* Athlone Institute of Technology, Co. Westmeath, Ireland, 18–21st June 2018. Ireland, Technology Education Research Group, pp. 231-238.

Williams, P. J. (2000). Design: The only methodology of technology? Journal of Technology Education, 11(2), 48-60.

Williams, S., Clausen, M, G., Robertson, A., Peacock, S. and McPherson, K. (2012). 'Methodological Reflections on the use of Asynchronous Online Focus Groups in Health Research', *International Journal of Qualitative Methods*, vol. 11, no. 4, pp. 368-383.

Wooff, D. (2017) 'Defining Design and Technology in an Age of Uncertainty: The View of the Expert Practitioner', *Prism*: *Casting New Light on Learning, Theory and Practice,* vol 1, no. 2, pp. 22-54.

Worth, J. and Faulkner-Ellis, H. (2021) *Teacher Labour Market in England* [Online], Slough. NFER. Retrieved 24 March 2021 from https://www.nfer.ac.uk/media/4382/teacher_labour_market_in_england_annual_report_2021.pdf

---

[i] GCSE: General Certificate of Secondary Education, a qualification studied by pupils in upper secondary and examined in their final year of secondary school, typically when they are aged 16.

[ii] According to the Department of Education (2019) "The EBacc is a set of subjects at GCSE that keeps young people's options open for further study and future careers. The EBacc is:

- English language and literature
- mathematics
- the sciences
- geography or history
- a language"

D&T is not included in the EBacc.

Design and Technology Education: An International Journal

28.2

# The Place of Design Education in Achieving 4IR Sustainability through the 4Cs Skill-sets

**Peter Oluwagbenga Odewole, Olabisi Onabanjo University, Nigeria**
**Tolulope Oladimeji Sobowale, Olabisi Onabanjo University, Nigeria**
**Festus Osarumwense Uzzi, Olabisi Onabanjo University, Nigeria**

## Abstract
The Fourth Industrial Revolution (4IR) merges the physical, digital, and biological spheres, reshaping societies and individuals worldwide in unprecedented ways. With the fast-moving globalization and rapid rate of technological development of the 4IR, the world is also facing unprecedented social, economic, and environmental challenges. As the 4IR continues to reshape industries across the globe, there is an increasing need for educational systems to adapt and equip students with the necessary skills to thrive in this rapidly evolving landscape. With its diverse socio-economic context and pressing environmental concerns, a specific emphasis on design education is required to develop a skilled workforce capable of driving sustainability in the 4IR. Given the needs of the 4IR, students need to possess a set of skills that are highly sought after. These skills, commonly known as the "4Cs," encompass communication, creativity, critical thinking, and collaboration. Design education plays a substantial role in preparing students for the demands of the 4IR, as it cultivates a holistic and interdisciplinary approach to problem solving, innovation, and sustainable development. This paper explores the place of design education in nurturing the 4Cs skill sets for achieving 4IR sustainability, focusing on how design education can address the unique challenges and opportunities faced in the 4IR era.

## Keywords
Design Education, 4IR Sustainability, 4Cs Skill-sets, Design Thinking

## Introduction
With the fast-moving globalization and rapid rate of technological development of the fourth industrial revolution (4IR), the world is also facing unprecedented social, economic, and environmental challenges (Schleicher, 2018). Therefore, while there is a sense of urgency to adopt 4IR technologies, adequate learning is required to achieve sustainable development in the 4IR era in such a way as to provide services for improving the quality of life (Ally & Wark, 2019). The Industrial Revolutions, including the IR, 2IR, 3IR, and the ongoing 4IR, emerged due to advancements in science, technology, and societal culture, each driven by the goal of enhancing the quality of human life. Design thinking, as obtainable in design education, served as a veritable tool for driving the technological innovations of the first, second, and third industrial revolutions (1IR, 2IR, and 3IR) and even the most recent 4IR (Adelabu, Akinbogun & Odewole, 2019).

The 4IR is characterized by innovations transforming activities in all sectors of human activities, generated by the convergence of emerging technologies such as big data and analytics, cloud computing, artificial intelligence (AI), internet of things (IoT), robotics, virtual and augmented reality, and more (Kasza, 2019). However, despite the 4IR technologies' immense potential, they also create concerns about the future, given that they could exert increased pressure on the earth, its resources, and human life (Zervoudi, 2019). Consequently, it is imperative to take necessary measures through education to fully harness the potential of the 4IR to transform the world, improve the well-being of individuals, and open up new avenues for global sustainable development, thereby expediting progress towards a sustainable future (Tejedor, et al., 2022). With sustainability in mind, it is evident that design education has a more critical role in the fourth industrial revolution than in all the previous eras. Skill sets required to prepare a workforce that can be sustained during the 4IR have been identified to include workforce readiness and soft, technical, and entrepreneurship skills (Armstron et al., 2018). Since the design field promotes skill-based learning, a key challenge in the 4IR is to explore approaches that promote societal and environmental sustainability by sharpening the required skill sets in the students before graduation. By identifying the significance of design education in developing the required skills for 4IR sustainability, students can proactively prepare for the challenges and opportunities presented by this transformative era.

Identifying barriers to effective design education in the context of 4IR sustainability is crucial for overcoming challenges and ensuring that students receive the necessary knowledge and skills to thrive in this rapidly evolving landscape. Incongruent with the challenges of education for sustainable development and constraints of education for the 4IR (Education 4.0), the main barriers that may hinder effective design education in the 4IR sustainability context include outdated curricula and a lack of resources or expertise in emerging technologies (Leicht, et al., 2018; Constan et al., 2021). These may impede students' ability to acquire the necessary skills to address sustainability issues in the 4IR. Since the 4IR is characterized by exponential technological advancements such as artificial intelligence, robotics, and automation, keeping up with these rapid changes and incorporating them effectively into design education can be challenging. Obstacles to interdisciplinary collaboration, such as rigid academic structures, limited opportunities for cross-disciplinary interaction, and the lack of integrated curriculums, can impede effective design education in the 4IR sustainability context (Leicht, et al., 2018; Constan et al., 2021). Limited access to vital resources, such as state-of-the-art technology, materials, and tools, particularly in educational institutions with financial constraints, can hinder students' ability to explore innovative and sustainable design solutions (Leicht, et al., 2018; Constan et al., 2021). A lack of engagement and collaboration between educational institutions and industry partners can hinder students' exposure to real-world challenges and limit their understanding of industry expectations and practices (Ankrah & AL-Tabbaa, 2015). This can result in limited opportunities for internships and industry projects that restrict students' ability to develop practical skills and gain industry insights relevant to 4IR sustainability. Resistance to change among educators and students can be a barrier (Sun & Turner, 2022). Overcoming deeply ingrained traditional design practices and fostering a sustainability mindset may require comprehensive educational reforms, educator professional development opportunities, and targeted awareness campaigns (Riel et al., 2015; Conway, Leahy, & McMahon, 2021).

In the 4IR era, individuals must have the necessary skills and competencies to thrive and contribute effectively to sustainable development. With the right skills in place, students can embrace the potential of the 4IR, contribute to innovation, and create sustainable solutions that address societal, economic, and environmental challenges. Design education's role in developing these skill sets is crucial for achieving a sustainable and inclusive future in the 4IR era. The 4Cs skills - communication, creativity, critical thinking, and collaboration - are essential for thriving in the 4IR context and achieving the Sustainable Development Goals (SDGs) (Ruminar & Gayatri, 2018). By nurturing the development of the 4Cs skills, design education equips individuals with the tools and mindset needed to tackle complex sustainability challenges in the 4IR. By cultivating critical thinking, interdisciplinary collaboration, empathy, and technological proficiency, design education prepares students to address the complex challenges and opportunities of the 4IR while driving sustainable development. A comprehensive understanding of design education's role in developing the 4Cs skill sets can pave the way for a more sustainable and prosperous future in the 4IR era. Design education promotes design thinking, which prepares students to become adaptable, empathetic, and innovative problem solvers who can navigate the evolving landscape of technology, society, and sustainability (Charles, 2022). Therefore, this article aims to explore in-depth how the 4Cs skills are integral to achieving sustainability goals within the 4IR context, how design education and design thinking foster the development of the 4Cs skills, and how relevant models and theories can be adopted for improving the 4Cs skills in design education for ensuring 4IR sustainability.

## Methodology

Using an integrative literature review, the study establishes the place of design education in achieving 4IR sustainability through the 4Cs skill sets. According to Snyder (2019), the primary goal of an integrative review is to evaluate, analyze, and combine existing literature pertaining to a specific research subject, facilitating the emergence of novel theoretical frameworks and perspectives. The study followed the systematic steps typical of an integrative review, which encompassed formulating one or more review questions, pinpointing all relevant electronic databases and sources for exploration, constructing a well-defined search strategy, scrutinizing titles, abstracts, and articles against predetermined inclusion and exclusion criteria, and systematically extracting data from chosen literature in a standardized format (Toronto, 2020).

The research questions for this study are as follows: (i) How can the 4Cs skill-sets help in achieving sustainability in the 4IR era? (ii) How can design education promote the development of the 4Cs skills needed for 4IR sustainability? (iii) What is the significance of design thinking towards advancing 4IR sustainability? (iv) What are the relevant theories and models that may be adopted to improve 4Cs skills in design education for 4IR sustainability? To answer these questions, a university database search engine and Google Scholar web search engine were used to identify potential articles. Searches were conducted on the database to identify relevant studies using the following terms: “design education” AND “4IR”, “design education” AND “SDGs,” “4Cs skills” AND “SDGs,” “design thinking” AND “sustainable development goals,” "academia and industry collaboration in the 4IR”, communication” AND “SDGs,” “creativity” AND “SDGs,” “critical thinking” AND “SDGs,” “collaboration” AND “SDGs,”.” This procedure yielded results considered as the initial samples.

After incorporating the specified keywords, the following inclusion and exclusion criteria were considered for selecting the final sample: the articles must be a peer-reviewed journal publication in English, accessible through university-subscribed or open-access journal databases, and have titles, abstracts, and full-texts that are directly related to the study. Publications that failed to meet these criteria were excluded. A comprehensive full-text analysis of these articles was then performed to determine their relevance to the research questions under consideration, resulting in a final sample of articles used in the study.

## The 4Cs Skill Sets for 4IR Sustainability

The core of the United Nations' 2030 Agenda comprises 17 Sustainable Development Goals (SDGs) introduced in 2015 (Rieckmann et al., 2017; Halkos & Gkampoura, 2021). Table 1 shows the summary of the 17 SDGs (United Nations, 2015). These goals aim to tackle social, economic, and environmental issues to ensure a sustainable, peaceful, prosperous, and equitable life for the present and future generations (Rieckmann et al., 2017; Halkos & Gkampoura, 2021).

***Table 1. The 17 Sustainable Development Goals (SDGs)***

| Number | Description | Objective |
|---|---|---|
| SDG 1 | No Poverty | End poverty in all its forms everywhere. |
| SDG 2 | Zero Hunger | End hunger, achieve food security and improved nutrition, and promote sustainable agriculture. |
| SDG 3 | Good Health and Well Being | Ensure healthy lives and promote well-being for all at all ages. |
| SDG 4 | Quality Education | Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. |
| SDG 5 | Gender Equality | Achieve gender equality and empower all women and girls. |
| SDG 6 | Clean Water and Sanitation | Ensure availability and sustainable management of water and sanitation for all. |
| SDG 7 | Affordable and Clean Energy | Ensure access to affordable, reliable, sustainable, and clean energy for all. |
| SDG 8 | Decent Work and Economic Growth | Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all. |
| SDG 9 | Industry, Innovation and Infrastructure | Build infrastructure, promote inclusive and sustainable industrialization, and foster innovation. |
| SDG 10 | Reduced Inequalities | Reduce inequality within and among countries. |
| SDG 11 | Sustainable Cities and Communities | Make cities and human settlements inclusive, safe, resilient, and sustainable. |
| SDG 12 | Responsible Consumption and Production | Ensure sustainable consumption and production patterns. |
| SDG 13 | Climate Action | Take urgent action to combat climate change and its impacts. |
| SDG 14 | Life below Water | Conserve and sustainably use the oceans, seas, and marine resources for sustainable development. |
| SDG 15 | Life on Land | Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation, and halt biodiversity loss. |
| SDG 16 | Peace, Justice, and Strong Institutions | Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels. |
| SDG 17 | Partnership for the Goals | Strengthen the implementation and revitalize the global partnership for sustainable development |

The challenge in the future lies not in a lack of employment opportunities but rather in a scarcity of the skills required for the new jobs that will emerge (Ruminar & Gayatri, 2018). This observation emphasizes the importance of developing the necessary skills to ensure sustainability in the 4IR context. The 4Cs skills can play a crucial role in advancing the SDGs by enabling individuals and organizations to think critically, communicate effectively, collaborate efficiently, and develop innovative solutions to address the complex challenges of sustainable development. These skills are interrelated and can be applied to various aspects of the SDGs, making them essential tools for achieving global goals. By recognizing the interconnectedness of the 4Cs skills and the SDGs, students can actively contribute to sustainable development. According to Thornhill-Miller et al. (2022), the 4Cs skills should not be viewed as entirely independent components but rather as interconnected fundamental "elements" for forward-thinking education, which can support individuals in their learning journey and, when combined, have a synergistic effect, enabling the growth of their cognitive abilities. Honing the 4Cs skills will empower students to foster a culture of creativity/critical thinking and promote collaborative initiatives to thrive in the 4IR era while working toward realizing the SDGs.

**Communication Skills.**

Effective communication is vital for promoting the SDGs (Genç, 2017; Khairil et al., 2018; Oueiss & El-Khoury, 2023). Individuals can raise awareness about sustainable development issues by articulating ideas, advocating for change, and engaging with diverse stakeholders. Communication skills are instrumental in fostering dialogue, mobilizing support, and facilitating collaborations among different sectors of society to work towards the SDGs. Since intricate and unpredictable factors generally mark sustainability-related concerns, effective communication is crucial in disseminating information among various stakeholders to ensure business success (Genç, 2017). Communication skills can contribute to SDG 4 (Quality Education) by promoting effective communication and information sharing in educational settings, ensuring inclusive access to education for all. Communication skills enable individuals to convey ideas, concepts, and solutions effectively. In the 4IR, where diverse stakeholders collaborate across borders and disciplines, communicating clearly and persuasively becomes paramount to achieving the SDGs (Armstron et al., 2018; Mhlanga & Moloi, 2020).

**Creativity Skills**

Creativity and innovation have emerged as crucial factors for success in the twenty-first century, vital in driving organizational achievements across various sectors (Shu, et al., 2020). Creativity is a powerful driver for sustainable development (Awan, Sroufe, & Kraslawski, 2019; Nakao & de Andrade-Guerra, 2019; d'Orville, 2019; Mróz & Ocetkiewicz, 2021). According to d'Orville (2019), creativity has emerged as a significant catalyst in the current knowledge and learning economy era, propelling society toward sustainability through its remarkable ability to imagine and envision transformative possibilities. By thinking innovatively and outside traditional approaches, individuals can develop new solutions to address complex challenges related to poverty, inequality, climate change, and more. Creative thinking can lead to the development of sustainable technologies, eco-friendly practices, and inclusive business models that contribute to achieving the SDGs (Falvey, 2018; d'Orville, 2019; Awan, Sroufe, & Kraslawski, 2019). Creativity is relevant to SDG 9 (Industry, Innovation, and Infrastructure) by driving the development of sustainable technologies and fostering innovation in industries that promote economic growth and job creation. To effectively address the complex and uncertain nature of sustainability challenges, it is essential to possess capabilities for creativity and innovation rather than relying solely on skills focused on repeating existing practices and ideas (Sandi, 2013). Creativity is the driving force behind innovation and problem solving (Sandri, 2013; Chiruguru, 2020; Mróz & Ocetkiewicz, 2021; Ibeh, et al., 2023). In the 4IR sustainability context, creative thinking is crucial for designing sustainable solutions that balance economic, social, and environmental considerations.

**Critical Thinking Skills**

Critical thinking is vital in the 4IR, where technological advancements introduce new challenges and ethical dilemmas. Critical thinking skills are essential for analyzing the multifaceted issues surrounding sustainable development (Minott, et al., 2019; Kaur, 2021; Taimur & Sattar, 2019). Individuals who can evaluate information critically and assess the social, economic, and environmental implications of decisions are better equipped to make informed choices that align with the SDGs. Critical thinking also helps identify potential trade-offs and balance competing priorities in pursuing sustainable development. Critical thinking is needed when evaluating the efficacy of interventions, strategies, projects, and policies, especially when assessing the SDGs' accomplishment (Schwandt et al., 2016; Taimur & Sattar, 2019). Critical thinking is indispensable for everyone responsible for achieving the SDGs (Schwandt et al., 2016; Straková & Cimermanová, 2018; Chiruguru, 2020). Critical thinking skills are essential for analyzing complex problems, evaluating information, and making informed decisions. Critical thinking skills are germane in designing solutions to achieve all the 17 SDGs to terminate poverty, safeguard the planet, and guarantee inclusive prosperity.

**Collaboration Skills**

Collaboration is central to addressing the multifaceted challenges of sustainability in the 4IR. No single discipline or individual can tackle these complex challenges alone in isolation (Braßler & Sprenger, 2021). By fostering collaboration among governments, businesses, civil society organizations, and communities, individuals can pool resources, expertise, and knowledge to find sustainable solutions. Collaborative sustainability-oriented innovations generate benefits that influence various aspects of value creation, encompassing intrinsic and extrinsic dimensions (Stibbe et al., 2018; Mariani et al., 2022). Collaboration through interdisciplinary teamwork has been recognized as crucial for driving sustainable development (Braßler & Block, 2017; Velásquez, et al., 2023). The challenges associated with achieving the targets of the SDGs are intricate and cannot be effectively addressed within the confines of a single discipline (Braßler & Block, 2017; Hackett, 2020; Braßler & Sprenger, 2021). Instead, they necessitate collaboration across different fields of expertise. By integrating sustainability and interdisciplinary collaboration, a comprehensive understanding of these complex issues can be attained, leading to the discovery of practical solutions (Braßler & Block, 2017; Enechi & Pattberg, 2020; Stuart & Mataix, 2021; Higgins & Smith, 2022). Collaboration plays a central role in SDG 17 (Partnerships for the Goals), as it encourages cross-sector collaboration and international cooperation to mobilize resources, build capacity, and accelerate progress towards all SDGs. Collaborative approaches enhance collective problem solving, promote social cohesion, and create synergies that accelerate progress toward the SDGs.

## How Design Education develops the 4Cs Skills for 4IR Sustainability

Design education nurtures effective communication by encouraging students to articulate their thoughts visually, verbally, and in written form (Zande, 2011; Cezzar, 2020). Communication is a crucial part of any design process, and any shortcomings in design communication can result in delays, errors, and even the ultimate failure of the entire process (Eckert, et al., 2005; Sandeep et al., 2021). The designer's typical objective involves communicating a specific design proposal using one or more drawings, which provide a comprehensive view of the artifact and specific details. Design education cultivates creativity by encouraging students to explore multiple perspectives, challenge assumptions, and think beyond conventional boundaries (Zande, 2011; Rosen, et al., 2020; Zhongbin, 2023). The primary purpose of design education is to harness the innate creative abilities of individuals and foster the development of innovative products in intellectual, social, and cultural domains (Kilicaslan & Ziyrek, 2012; Daskova et al., 2020). It provides opportunities for experimentation, risk-taking, and exploring new materials, technologies, and design methodologies. Design education fosters critical thinking by teaching students to question, analyze, and evaluate information from multiple sources, encouraging them to consider the broader implications of their designs, such as their environmental impact, social equity, and long-term sustainability (Keane & Keane, 2019; Zhongbin, 2023).

Design education encourages collaboration and interdisciplinary approaches (Zande, 2011; McDermott, et al., 2014; Kaygan & Demir, 2017; Cohen & Mule, 2019; Petrova et al., 2022). Design education promotes collaboration by providing opportunities for interdisciplinary projects, teamwork, and stakeholder engagement. It encourages students to work collaboratively, leverage diverse perspectives, and embrace the collective problem-solving approach. By fostering interdisciplinary collaborations, design education enables students to tackle systemic challenges and create sustainable solutions considering a society's diverse needs and contexts. Collaboration enhances the effectiveness and impact of design solutions, fostering a holistic approach to 4IR sustainability. Design education instills a sense of empathy and social responsibility (Zande, 2011; López-León & Valdez, 2017; Bosch, Härkki & Seitamaa-Hakkarainen, 2022). Students are encouraged to consider their design decisions' social and environmental implications. This awareness is crucial for 4IR sustainability, where issues such as inequality, poverty, and environmental degradation are prevalent. By emphasizing ethical and sustainable design practices, students can contribute positively to society and drive change toward a more inclusive and environmentally conscious future.

## Design Thinking and 4IR Sustainability

Design education nurtures design thinking, a powerful tool for fostering innovation and problem-solving abilities in the 4IR era. Design thinking is a human-centered problem-solving methodology that encourages creative and innovative solutions (Lor, 2017). Through design thinking methodologies, students learn to identify problems, empathize with users, and prototype innovative solutions. According to Lor (2017) analysis of the application of a design-thinking framework, design thinking can promote 4IR sustainability by adopting an empathy and a user-centric approach, developing an iterative and experimental mindset, encouraging multidisciplinary collaboration, stimulating creativity and ideation, and emphasizing human-centered prototyping and testing.

Design thinking ensures that user insights drive innovation, starting with understanding the end-users' needs, perspectives, and experiences and empathizing with the people for whom the solutions are intended (Deepa, 2020; Wible, 2022). This approach is especially relevant in the 4IR era, where technology transforms interactions between humans and systems. Design thinking enables individuals to identify significant problems, develop user-centric solutions, and enhance the overall user experience, embracing an iterative and experimental problem-solving approach (Foster, 2019; Deepa, 2020; Wible, 2022). Instead of pursuing a linear path, design thinkers develop prototypes and test their ideas early and frequently. This iterative process allows for feedback, learning, and refinement. In the 4IR era, where technologies evolve rapidly, an iterative mindset helps individuals adapt and respond to changing circumstances, fostering agility and resilience to face uncertainties.

Design thinking stimulates creative thinking and idea generation, providing a structured framework to explore new possibilities, challenge assumptions, and break away from conventional thinking (Deepa, 2020; Wible, 2022). This creative approach is essential in the 4IR era, where innovation is a crucial driver of success. Design thinking encourages individuals to embrace ambiguity, explore unconventional solutions, and unlock their creative potential to address emerging challenges and leverage technological advancements (Abell & DeVore, 2017). Design thinking emphasizes the creation of tangible prototypes to bring ideas to life, which are then tested and refined based on user feedback (Deepa, 2020; Wible, 2022). By involving users early in the process and incorporating their insights, design thinking ensures that solutions are relevant, effective, and user-friendly. This approach is valuable in the 4IR era, where technology can be complex and rapidly evolving since prototyping and testing allow individuals to validate ideas, identify potential issues, and iterate on their solutions to optimize outcomes.

Design thinking encourages collaboration across disciplines and diverse perspectives. It brings together individuals with different expertise, backgrounds, and knowledge to generate a rich pool of ideas and solutions. Collaboration is essential in the 4IR era, where complex challenges often require diverse skill sets. By fostering interdisciplinary collaboration, design thinking enables the synthesis of different perspectives, leading to more comprehensive and innovative solutions. By employing empathy, experimentation, collaboration, creativity, and human-centric prototyping, design thinking enables individuals to navigate the complexities of the 4IR landscape, develop innovative solutions that address societal needs, and leverage emerging technologies. Embracing design thinking as a mindset and integrating it into educational and organizational contexts can empower individuals to thrive in the 4IR by fostering a culture of creativity and innovation, adaptability, user-centered problem solving, and the ability to anticipate and navigate emerging technologies and societal shifts, all of which are fundamental for sustainable development in the 4IR.

## Theories and Model to Improve 4Cs Skills in Design Education for 4IR Sustainability

### Social Learning Theory and Social Cognitive Theory

The Social Cognitive Theory, developed in 1986, evolved from the Social Learning Theory (SLT) developed by Albert Bandura in 1960 (Koutroubas & Galanakis, 2022), offer valuable insights into how design education can apply its principles to acquire the 4Cs skills (Critical thinking, Creativity, Collaboration, and Communication) needed for the 4IR sustainability. The Social Learning Theory posits that learning occurs through observation, imitation, and social interaction (Lyons & Berge, 2012; Koutroubas & Galanakis, 2022). Design education can leverage Social Learning Theory by promoting collaborative projects, peer learning, and mentorship, allowing students to acquire and refine their 4Cs skills through interactions with peers, instructors, and professionals.

The Social Cognitive Theory highlights the importance of observational learning, where individuals acquire new knowledge, behaviours, and skills by observing others (Koutroubas & Galanakis, 2022). The theory highlights the reciprocal interaction between individuals, their environment, and their cognitive processes, providing a framework for understanding how design education can foster the development of these essential skills. In the context of design education, students can benefit from observing and modeling the behaviours and skills of experienced designers, mentors, and industry professionals. By providing opportunities for students to witness real-world design processes, collaboration, and effective communication, design education can enhance the 4Cs skills by exposing students to successful role models (Starčič & Lebeničnik, 2020).

The Social Cognitive Theory emphasizes the role of self-efficacy, which refers to an individual's belief in their ability to perform a specific task (Koutroubas & Galanakis, 2022). Design education can enhance students' self-efficacy in the 4Cs skills by providing scaffolded learning experiences, constructive feedback, and opportunities for success. By gradually increasing the complexity of design tasks and providing support and recognition for students' achievements, design education can help students build confidence and competence in critical thinking, creativity, collaboration, and communication. The theory underscores the importance of self-regulation, which involves setting goals, monitoring progress, and adjusting behaviours to achieve desired outcomes (Bandura, 1991). In design education, students can be encouraged to set goals for their learning and design projects, monitor their progress, and reflect on their strategies and outcomes. By promoting self-regulation, design education supports the development of students' metacognitive skills, enabling them to effectively plan, monitor, and evaluate their use of the 4Cs skills in designing sustainable solutions for the 4IR.

The Social Cognitive Theory recognizes the influence of environmental factors on individual learning and behaviour, emphasizing the importance of social interaction and learning from others (Govindaraju, 2021). Design education can create an environment that supports the development of the 4C skills by providing collaborative spaces, tools, and resources for students to engage in meaningful design projects. By fostering a culture of collaboration, open communication, and interdisciplinary interactions, design education can facilitate the development of the 4Cs skills in response to the complex sustainability challenges of the 4IR. Design education can foster social learning by promoting collaborative design projects, group discussions, and peer feedback. By providing opportunities for students to engage in collaborative problem-solving, design education supports the development of the 4Cs skills in the context of teamwork, negotiation, and effective communication.

**Experiential Learning Theory**

Experiential Learning Theory (ELT), developed by David Kolb in 1984, provides a valuable framework for understanding and applying design education principles to acquire the 4Cs skills needed for 4IR sustainability. The Experiential Learning Theory suggests that learning occurs through a cycle of concrete experiences, reflection, abstract conceptualization, and active experimentation (Kolb & Kolb, 2005). The theory emphasizes the importance of hands-on experiences, reflection, and active engagement in the learning process, offering insights into how design education can foster the development of these essential skills. Experiential learning can be integrated into design education to enhance the acquisition of 4Cs skills by providing hands-on experiences and opportunities for critical thinking, creativity, collaboration, and communication.

The theory suggests that learning is most effective based on concrete experiences (McCarthy, 2010). In design education, concrete experiences mean providing students with authentic, real-world design challenges and projects related to 4IR sustainability. By engaging in concrete experiences, students can apply the 4Cs skills in practical contexts. This allows a deeper understanding of how these skills contribute to sustainable design practices. The Experiential

Learning Theory emphasizes the importance of reflective observation, which involves stepping back and carefully observing one's experiences and the experiences of others (McCarthy, 2010). Design education can incorporate structured reflection activities, such as journaling, group discussions, or critique sessions, to encourage students to reflect on their design processes, outcomes, and the impact of their work on sustainability. This reflective observation helps students refine their critical thinking skills, gain insights into their creative processes, improve collaboration, and develop effective communication strategies.

The theory suggests abstract conceptualization, which means that individuals must make sense of their experiences by transforming them into abstract concepts and theories (McCarthy, 2010). In design education, students can engage in critical analysis, concept mapping, and theory development related to 4IR sustainability. By abstract conceptualization, students deepen their understanding of the underlying principles and theories that guide sustainable design practices, enhancing their critical thinking skills and fostering creative problem-solving. The ELT highlights the importance of active experimentation, which involves applying new knowledge and skills to solve problems and create innovative solutions (McCarthy, 2010). Design education can provide opportunities for students to engage in prototyping, testing, and iterative design processes. By actively experimenting, students develop their creative thinking skills, learn from failures and successes, collaborate in problem-solving activities, and communicate their design ideas effectively to stakeholders.

The theory recognizes learning as a cyclical process involving concrete experience, reflective observation, abstract conceptualization, and active experimentation (Kolb & Kolb, 2005; Radović et al., 2021). Design education can incorporate iterative cycles of learning and practice, allowing students to revisit and refine their understanding of the 4Cs skills in the context of 4IR sustainability. This cyclical learning process encourages continuous improvement, adaptability, and the integration of the 4Cs skills into students' design practice. The Experiential Learning Theory encourages authentic assessment, which involves evaluating students' capabilities based on real-world performance and applying skills (Radović et al., 2021). Authentic assessment recognizes students applying the 4Cs skills in real-world contexts, promoting their ability to contribute to sustainable design practices in the 4IR. Design education can incorporate authentic assessment methods like project-based assessments, portfolio reviews, or stakeholder presentations. By assessing students' abilities to demonstrate the 4Cs skills in authentic contexts, design education ensures the alignment between acquiring these skills and their practical application in 4IR sustainability challenges.

**T-shaped Skills Model**

The T-shaped skills model provides a practical approach to design education to acquire the 4Cs skills needed for 4IR sustainability. The T-model was developed from the “T-shaped” concept coined by David Guest to describe the technologically proficient employees that would be essential in the near future (Garner & Estry, 2017). The model represents a combination of deep expertise in a specific domain (vertical bar of the "T") and a breadth of interdisciplinary skills and knowledge (horizontal bar of the "T") (Saviano et al., 2016). Design education can focus on developing the vertical bar of domain-specific skills while fostering the horizontal bar of interdisciplinary skills, including the 4Cs skills, to prepare students for 4IR sustainability challenges. The T-shaped skill set has been described as the most desirable for designers (Dekoninck & Bridge, 2023). The "T-shaped" conceptual representation of a designer's expertise entails broad knowledge of related professions horizontally and in-depth knowledge of design processes vertically (Baratta, 2017).

The model emphasizes the significance of possessing profound expertise in a particular field (represented by the vertical bar of the "T") while also highlighting the capacity to collaborate and communicate effectively across various fields (illustrated by the horizontal bar of the "T"), providing valuable insights into how design education can promote the cultivation of these essential skills. The vertical bar of the T-shaped skills model represents the depth of knowledge in a specific area. In design education, students should develop a strong foundation of knowledge in design principles, theories, and practices relevant to 4IR sustainability. This includes understanding the principles of sustainable design, technological advancements, and the social, economic, and environmental implications of the 4IR. Building this depth of knowledge allows students to critically analyze complex problems, think creatively, and develop innovative solutions. The horizontal bar of the T-shaped skills model represents the ability to collaborate and communicate across different disciplines. Design education should encourage students to collaborate in interdisciplinary teams, engaging with engineering, social sciences, technology, and business professionals. By collaborating with diverse stakeholders, students develop collaboration and communication skills, appreciate different perspectives, and understand sustainability challenges in the 4IR.

The model underscores the significance of cross-disciplinary knowledge, which involves understanding and integrating concepts and practices from multiple disciplines. In design education, students should be exposed to various disciplines relevant to 4IR sustainability, such as data analytics, renewable energy, social impact assessment, and user-centered design. This cross-disciplinary knowledge enables students to apply critical thinking and creativity to bridge gaps between disciplines, facilitating the development of innovative and sustainable design solutions. The model aligns well with design thinking principles and a human-centered problem-solving approach. The model recognizes the importance of effective communication and presentation skills. Design education should allow students to develop their communication skills, including visual communication, written and oral presentation skills, and storytelling techniques. By effectively communicating their design ideas, students can engage stakeholders, build consensus, and convey their sustainable design solutions' social and environmental benefits in the 4IR.

The model acknowledges the need for lifelong learning and adaptability in the rapidly changing landscape of the 4IR. Design education should foster a culture of continuous learning, encouraging students to stay updated with emerging technologies, new design methodologies, and evolving sustainability practices. By nurturing a mindset of lifelong learning, design education equips students with the ability to adapt to new challenges and acquire additional skills as needed, ensuring their continued relevance in the 4IR (Keane & Keane, 2019). The T-model equips students with the necessary abilities to survive and flourish in a complex and challenging world, where adaptability, innovation, and transcend boundaries are crucial for success (Garner & Estry, 2017).

## Recommendation

Design education should consider the interdisciplinary nature of the 4IR and encourage students to collaborate with individuals from various fields, such as engineering, computer science, and social sciences. This interdisciplinary approach will enable them to understand their designs' broader implications and applications and create holistic, sustainable, and adaptable solutions. Implementing interdisciplinary approaches in design education is essential, as this can significantly enhance the learning experience and prepare students for the diverse and complex challenges of the 4IR era. Interdisciplinary education encourages the integration of knowledge, methods, and perspectives from multiple disciplines, fostering a holistic understanding and fostering creativity and innovation. Implementing interdisciplinary approaches in design education helps students bridge disciplinary gaps, promoting innovation, providing integrated learning experiences, and cultivating flexibility and adaptability.

In the 4IR era, there is a need to encourage cross-cultural and diverse perspectives in design education to foster creativity, inclusivity, and a deeper understanding of global design challenges. This can be achieved by engaging teaching faculties from various cultural backgrounds and design disciplines can expose students to different design practices, philosophies, and creative processes; and by facilitating student exchanges and collaborations with design schools and universities worldwide to create opportunities for students to engage with different cultures and design traditions. Students must be encouraged to participate in collaborative projects with international partners that will enable them to consider diverse perspectives, understand cultural nuances, and develop cross-cultural communication and collaboration skills. Cultural awareness and sensitivity training must be incorporated into the design curriculum. It helps students appreciate diverse cultural practices, beliefs, and values, equipping them with the needed knowledge and skills to approach design challenges from a culturally sensitive and inclusive standpoint. By accommodating diversity and incorporating cross-cultural perspectives, design education prepares students to become culturally sensitive and inclusive designers who can navigate a multicultural world and create solutions that resonate with diverse audiences.

## Conclusion

To ensure a prosperous and inclusive future, educational institutions and policymakers must prioritize integrating design education within the broader educational framework, empowering students to become agents of positive change in the 4IR era. Design education prepares individuals to thrive in the 4IR era by equipping them with the necessary skills, fostering a sustainability mindset, and encouraging interdisciplinary collaboration. By embracing these principles, design education can contribute to shaping a future that harnesses the potential of the 4IR while addressing the pressing needs of our global community. To tackle the 4IR challenges, it is crucial to explore innovative approaches within design education that impart technical expertise and promote the development of skills that contribute to a sustainable society and environment. This includes fostering creativity, critical thinking, collaboration, and problem-solving abilities among students. By integrating these aspects into design education, future professionals can be empowered to address the complex social, economic, and environmental issues of the 4IR. Design education incorporates design thinking methodologies emphasizing empathy, iterative prototyping, and user-centered design processes. By adopting a design thinking mindset, students learn to approach complex sustainability challenges in the 4IR with critical thinking, creativity, and a collaborative spirit, leading to innovative and sustainable design solutions.

In the light of Social Learning Theory and Social Cognitive Theory, by leveraging observational learning, promoting self-efficacy and self-regulation, considering environmental factors, facilitating vicarious experiences, and fostering social learning, design education can create an effective learning environment that supports the development of the 4C skills in the context of sustainable design practices for the 4IR. The Experiential Learning Theory provides a comprehensive framework for design education to acquire the 4Cs skills needed for 4IR sustainability by incorporating concrete experiences, reflective observation, abstract conceptualization, active experimentation, and a cyclical learning process to foster the development of the 4Cs skills. The T-shaped skills model provides a comprehensive approach to design education to acquire the 4Cs skills needed for 4IR sustainability. In line with the T-shaped skills model, by combining depth of knowledge with collaboration, interdisciplinary skills, cross-disciplinary knowledge, design thinking, communication, and adaptability, design education prepares students to effectively address complex sustainability challenges and contribute to advancing sustainable design practices in the 4IR era.

It is noteworthy that not only individual students need to focus on design education for skill development but also educational institutions, governments, and businesses. Educational institutions should adapt design education into their curricula to incorporate 4IR-related subjects and foster skill-based learning approaches. Governments should prioritize investing in design education and training initiatives that equip individuals with the necessary skills for the 4IR workforce. Businesses should actively provide opportunities for upskilling and reskilling their employees through design education to ensure they remain competitive in a rapidly changing environment.

## References

Abell, A. & DeVore, K. (2017). Embracing ambiguity: A framework for promoting iterative design thinking approaches in Engineering and design curricula, *American Society for Engineering Education*, 1-30.

Adelabu, O.S., Akinbogun, T.L., & Odewole, P.O. (2019). Design education in Nigeria: the place of the fourth industrial revolution, Proceeding, Visual Communication Design Conference held at Federal University of Technology, Akure, Nigeria on 15-16 August 2019, 565-582. ISBN 1119-5010.

Ally M. & Wark N. (2019). Learning for sustainable development in the fourth industrial revolution, Conference Proceedings & Working Papers, 2019 Pan-Commonwealth Forum 9 (PCF9), pp. 1–7. Scotland. http://hdl.handle.net/11599/3393

Ankrah, S. & AL-Tabbaa, O. (2015). Universities—industry collaboration: A systematic review, *Scandinavian Journal of Management*, 31, 387-408. http://dx.doi.org/10.1016/j.scaman.2015.02.003

Armstrong K., Parmelee, M., Santifort, S., Burley, J., Fleet, J.V., Koziol, M., Greenberg, R., Schwartz, J., & Tetrick, R. (2018). Preparing tomorrow's workforce for the Fourth Industrial Revolution for business: A framework for action, Deloitte Global Business Coalition for Education, Available at: https://gbc-education.org/wp-content/uploads/sites/2/2022/03/Deloitte_Preparing-tomorrows-workforce-for-4IR-revised-08.11.pdf

Awan, U., Sroufe, R., & Kraslawski, A. (2019). Creativity enables sustainable development: Supplier engagement as a boundary condition for the positive effect on green

innovation, *Journal of Cleaner Production*, 226, 172-185. https://doi.org/10.1016/j.jclepro.2019.03.308
Baratta, D. (2017) The “T” shaped designer expertise. The “reverse-T” shaped designer horizon, *The Design Journal*, 20, sup1, S4784-S4786, DOI: 10.1080/14606925.2017.1352992
Bandura, A. (1991). Social cognitive theory of self-regulation, Organizational Behavior and *Human Decision Processes*, 50, 248-287.
Bosch, N., Härkki, T., & Seitamaa-Hakkarainen, P. (2022). Design empathy in students’ participatory design processes, *Design and Technology Education: An International Journal*, 27(1), 29-48.
Braßler, M., & Block, M. (2017). Interdisciplinary teamwork on sustainable development—the Top ten strategies based on the experience of student-initiated projects. In W. Leal Filho et al. (eds.), Handbook of Theory and Practice of Sustainable Development in Higher Education, World Sustainability Series, Springer, pp. 65-77. DOI: 10.1007/978-3-319-47877-7_5.
Braßler, M. & Sprenger, S. (2021). Fostering sustainability knowledge, attitudes, and behaviours through a tutor-supported interdisciplinary course in education for sustainable development, *Sustainability*, 13, 3494. https://doi.org/10.3390/su13063494
Cezzar, J. (2020). Teaching the designer of now: A new basis for graphic and communication design education, *She Ji: The Journal of Design, Economics, and Innovation*, 6(2), 213–227. https://doi.org/10.1016/j.sheji.2020.05.002
Charles, S. (2022). Design thinking, a novel approach for an effective and improved educational system–A review, *International Journal of Professional Development, Learners and Learning*, 4(1), ep2205, 1–5. https://doi.org/10.30935/ijpdll/12010
Chiruguru, S. B. (2020). The Essential Skills of 21st Century Classroom, *ResearchGate*, 1-14. https://doi.org/10.13140/RG.2.2.36190.59201
Cohen, R.M. & Mule, L. (2019). Collaborative pedagogy in a design thinking education course, *InSight: A Journal of Scholarly Teaching*, 14, 29-42.
Costan, E., Gonzales, G., Gonzales, R., Enriquez, L., Costan, F., Suladay, D., Atibing, N.M., Aro, J.L., Evangelista, S.S., Maturan, F., Selerio (Jr.), E., and Ocampo, L. (2021). Education 4.0 in developing economies: A systematic literature review of implementation barriers and future research agenda, *Sustainability*, 13(22), 12763. https://doi.org/10.3390/su13221276
Conway, B., Leahy, K., & McMahon, M. (2021). Design education for sustainability: Identifying opportunities in Ireland’s second level education system, Sustainability, 13, 8711. https://doi.org/10.3390/su13168711
Daskova Yu.V., Poliakova Ia.V., Vasilenko S.A., Goltseva O.S., Belyakova T.E., Shevalie K.N., & Vasilenko E.V. (2020). Development of creative independence of design students in course of higher education, *Propósitos y Representaciones*, 8(2) 1-12. Doi: http://dx.doi.org/10.20511/pyr2020.v8nSPE2.637
Dekoninck, E., Bridge, L. (2023). ‘The T-shaped design engineer – using cohorts to explore how skills profiles differ through career stages’, in Proceedings of the International Conference on Engineering Design (ICED23), Bordeaux, France, 24-28 July 2023, pp. 3533- 3542. DOI: 10.1017/pds.2023.354
Deepa, P. (2020). A study on the concepts of design thinking, International Journal of Engineering Applied Sciences and Technology, 4(12), 269–272.
d’Orville, H. (2019). The relationship between sustainability and creativity, *Cadmus Journal*, 4(1), 65–73.

Eckert, C.M., Maier, A.M., & McMahon, C. (2005). Communication in design. In J. Clarkson & C. Eckert (eds.) Design process improvement: A review of current practice, Springer-Verlag London, pp. 232-261. DOI: 10.1007/978-1-84628-061-0_10
Enechi, O. & Pattberg, P. (2020). Building strong partnership for SDGs: Analyzing participation of Nigerian stakeholders. In G. von Schnurbein (ed.), Transitioning to Strong Partnerships for the Sustainable Development Goals. Transitioning to Sustainability Series 17. Basel: MDPI, pp. 29-44. doi:10.3390/books978-3-03897-883-1
Falvey, L. (2018). Creativity and innovation for smart societies and sustainable development or smart R&D for increased sustainability? Conference Proceeding, Creativity and Innovation for Smart Societies and Sustainable Development, Phuket, Thailand.
Foster, M.K. (2019). Design thinking: A creative approach to problem solving, *Management Teaching Review*, 6(2), 123–140. https://doi.org/10.1177/2379298119871468
Garner, P., & Estry, D. (2017). A Primer on the T-professional. The Collegiate Employment Research Institute, Michigan State University. https://ceri.msu.edu/_assets/pdfs/t-shaped-pdfs/Primer-on-the-T-professional.pdf
Genç, R. (2017). The importance of communication in sustainability and sustainable strategies, *Procedia Manufacturing*, 8, 511–516. DOI: 10.1016/j.promfg.2017.02.065
Govindaraju, V. (2021). A review of social cognitive theory from the interpersonal communication perspective, *Multicultural Education*, 7(12), 488–492. DOI: 10.5281/zenodo.5802235
Hackett, E.J. (2020). Collaboration and sustainability: Making science useful, making useful science, *Sustainability*, 12(22), 9361. DOI: 10.3390/su12229361
Halkos, G. & Gkampoura, E.-C. (2021). Where do we stand on the 17 Sustainable Development Goals? An overview on progress, *Economic Analysis and Policy*, 70, 94-122. https://doi.org/10.1016/j.eap.2021.02.001
Higgins, L.E., & Smith, J.M. (2022). Documenting development of interdisciplinary collaboration among researchers by visualizing connections, *Research Evaluation*, 31(1), 159–172, https://doi.org/10.1093/reseval/rvab039
Ibeh, L.I., Ibeh, J.I., & Kaine, O.F. (2023). Promoting creativity and innovation thinking in tertiary institutions: A panacea for sustainable development, *Nigerian Journal of Management Sciences*, 24(2b), 335-339.
Kasza, J. (2019). Fourth industrial revolution (4IR): Digital disruption of cyber-physical systems, World Scientific News: An International Scientific Journal, 134(2), 118–147.
Kaur, K. (2021). Enhancing sustainable development through critical thinking in education: A multifaceted collaborative strategy, *International Journal of Research Publication and Reviews*, 2(11), 181–183.
Kaygan, P. & Demir, Ö. (2017). Learning about others: Developing an interdisciplinary approach in design education, Proceeding, Design Management Academy Conference: Research Perspectives on Creative Intersections, Hong Kong, pp. 1596-1611.
Keane, K. & Keane, M. (2019). Designing design education. https://bpb-us-w2.wpmucdn.com/voices.uchicago.edu/dist/a/1299/files/2019/07/sti2014_designing-design-education2.pdf
Khairil, M. et al. (2018). Communication strategy towards sustainable development goals (SDGs), *Journal of Food, Agriculture & Environment*, 16 (2), 191-193.
Kilicaslan, H., & Ziyrek, B.E. (2012). A research about creativity in design education, *Procedia – Social and Behavioral Sciences*, 46, 1461-1464. DOI: 10.1016/j.sbspro.2012.05.321

Kolb, A.Y., & Kolb, D.A. (2005). Learning styles and learning spaces: Enhancing experiential learning in higher education, Academy of Management Learning & Education, 4(2), 193–212.

Koutroubas, V., & Galanakis, M. (2022). Bandura's social learning theory and its importance in the organizational psychology context, *Psychology Research*, 12(6), 315-322. DOI: 10.17265/2159-5542/2022.06.001

Leicht, A., Heiss, J., & Byun, W.J. (2018). Issues and trends in education for sustainable development. UNESCO Publishing, pp. 7-16. https://doi.org/10.54675/YELO2332

López-León, R., & Valdez, G.G. (2018). Understanding empathy in design education, *International Journal of Educational Research and Innovation (IJERI)*, 10, 51-63.

Lor, R.R. (2017). Design thinking in education: A critical review of literature, Proceedings International Academic Conference on Social Sciences and Management (ACSSM) & Asian Conference on Education and Psychology (ACEP), Bangkok, Thailand, May 24-26, 2017, pp. 36-68.

Lyons, S.D., & Berge, Z.L. (2012). Social learning theory. In N.M. Seel (ed.), Encyclopedia of the Sciences of Learning, Springer Science+Business Media. DOI: 10.1007/978-1-4419-1428-6_1257

Mariani, L., Trivellato, B., Martini, M., & Marafioti, E. (2022). Achieving sustainable development goals through collaborative innovation: Evidence from four European initiatives*, Journal of Business Ethics*, 180, 1075–1095. https://doi.org/10.1007/s10551-022-05193-z

McCarthy, M. (2010). Experiential learning theory: From theory to practice, *Journal of Business & Economics Research*, 8(5), 131-140.

McDermott, L., Boradkar, P., & Zunjarwad, R. (2014). Interdisciplinarity in design education: Benefits and challenges. IDSA Education Symposium, Austin, 13 August, 2014.

Mhlanga, D., & Moloi, T. (2020). The stakeholder theory in the fourth industrial revolution, *International Journal of Economics and Finance Studies*, 12(2), 352-368. Doi: 10.34109/ijefs.202012207

Minott, D., Ferguson, T., & Minott, G. (2019). Critical thinking and sustainable development. In: Leal Filho, W. (eds) Encyclopedia of Sustainability in Higher Education. Springer, Chapter C, pp. 1–6. https://doi.org/10.1007/978-3-319-63951-2_529-1

Mróz, A., & Ocetkiewicz, I. (2021). Creativity for sustainability: How do Polish teachers develop students' creativity competence? Analysis of research results, *Sustainability*, 13(2), 571. https://doi.org/10.3390/su13020571

Nakao, B.H. & de Andrade-Guerra, J.B. (2019). Creativity, innovation, and sustainable development. In W. Leal Filho et al. (eds.), Decent Work and Economic Growth, Encyclopaedia of the UN Sustainable Development Goals, Springer Nature Switzerland AG, Chapter D, pp. 1-12. https://doi.org/10.1007/978-3-319-71058-7_55-1

Oueiss, E.A. & El-Khoury, J.R. (2023). Media strategies for promoting sustainable development goals, *Arab Media & Society*, 34, 1-20.

Petrova, M.N., de Steffen, M.D.C.C., Piumatti, R.G. & Lingán, C.R.L. (2022). Collaborative learning in international interdisciplinary teams, International Conference on Engineering and Product Design Education, 8–9 September 2022, London South Bank University, London, UK.

Rieckmann, M., Mindt. L., & Gardiner, S. (2017). Education for sustainable development goals: Learning objectives. The United Nations Educational, Scientific and Cultural Organizations (UNESCO).

Riel, A., Lelah, A., Mandil, G., Rio, M., Tichkiewitch, S., Zhang, F., & Zwolinski, P. (2015). An innovative approach to teaching sustainable design and management, Procedia *CIRP*, 36, 29 –34. doi: 10.1016/j.procir.2015.01.059

Rosen, Y., Stoeffler, K., & Simmering, V. (2020). Imagine: Design for creative thinking, learning, and assessment in schools, *J Intell.*, 8(2), 16. doi: 10.3390/jintelligence8020016

Ruminar, H., & Gayatri, P. (2018). Incorporate 4C's skills in EFL teaching and learning to face education challenges in the 4IR, Proceeding, The First International Conference On Teacher Training and Education 2018 (ICOTTE 2018). The University of Islam Malang (UNISMA).

Sandeep, K., Carlye, L. Christopher, M. Catherine, B., & Jessica, M. (2021). Novice designers' use of prototypes as communication tools, International Conference on Engineering Design (ICED21), 16-20 August 2021, Gothenburg, Sweden.

Sandri, O. J. (2013). Exploring the role and value of creativity in education for sustainability, *Environmental Education Research*, 19(6), 765–778. DOI:10.1080/13504622.2012.74997

Saviano, M., Polese, F., Caputo, F., & Walletzký, L. (2016). A T-shaped model for rethinking higher education programs, Proceeding, 19th Toulon-Verona International Conference, University of Huelva, Huelva (Spain), 5-6 September 2016, pp. 425-440.

Schleicher, A. (2018). The future of education and skills: education 2030. Available at: https://www.oecd.org/education/2030/E2030%20Position%20Paper%20(05.04.2018).pdf

Schwandt, T., Ofir, Z., D'Errico, S., El-Saddik, K. & Lucks, D. (2016). Realising the SDGs by reflecting on the way(s) we reason, plan and act: the importance of evaluative thinking, *IIED Briefing*, 1-4. http://pubs.iied.org/17380IIED

Shu, Y., Ho, S.-J., & Huang, T.-C. (2020). The development of a sustainability-oriented creativity, innovation, and entrepreneurship education framework: A perspective study, *Front. Psychol.*, 11, 1878. DOI: 10.3389/fpsyg.2020.01878

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines, *Journal of Business Research*, 104, 333–339. https://doi.org/10.1016/j.jbusres.2019.07.039

Starčič, A.I. & Lebeničnik, M. (2020). Investigation of university students' perceptions of their educators as role models and designers of digitalized curricula, Human Technology, 16(1), 55–91. DOI: https://doi.org/10.17011/ht/urn.202002242163

Stibbe, D., Reid, S., Gilbert, J., Raphael, L., Findlay, R., Albana Spiro, A., de Villiers, I., Wisheart, M., & Goransson, O. (2018). Maximising the impact of partnerships for the SDGs: A practical guide to partnership value creation, The Partnering Initiative and United Nations Department of Economic and Social Affairs (UN DESA).

Straková, Z. & Cimermanová, I. (2018). Critical thinking development—A necessary step in higher education transformation towards sustainability, *Sustainability*, 10(3366), 1-18. doi:10.3390/su10103366

Stuart, K. & Mataix, C. (2021). Preface. In D.F. Murphy & L. Stott (eds.) Partnerships for the sustainable development goals (SDGs), MDPI, pp. ix.

Sun, J.C. & Turner, H.A. (2022). The complementarity investment in university-industry collaboration, *Innovative Higher Education*, 48, 539–556. https://doi.org/10.1007/s10755-022-09641-6

Taimur, S. & Sattar, H. (2019). Education for sustainable development and critical thinking competency. In W.Leal Filho et al. (eds.), Quality Education, Encyclopedia of the UN

Sustainable Development Goals, Springer, Chapter E, pp. 1-12. https://doi.org/10.1007/978-3-319-69902-864-1
Tejedor, G., Sánchez-Carracedo, F., & Segalàs, J. (2022), *Sustainability*, 14(10530), 1-6. https://doi.org/10.3390/su141710530
Thornhill-Miller, B. (2023). Creativity, critical thinking, communication, and collaboration: assessment, certification, and promotion of 21st-century skills for the future of work and education, *Journal of Intelligence*, 11(54), 1-32. DOI: 10.3390/jintelligence11030054
Toronto, C.E. (2020). Overview of the integrative review. In C.E. Toronto & R. Remington (eds.), A Step-by-Step Guide to Conducting an Integrative Review. Springer Nature Switzerland AG, pp. 1–9. https://doi.org/10.1007/978-3-030-37504-1
United Nations (2015). Transforming our world: The 2023 agenda for sustainable development. https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf
Velásquez, H., Guerra, M.A., & Jiménez, M. (2023). WIP: Measuring interdisciplinary teams´ sustainable design with an SDG lens, Proceedings, Annual Conference and Exposition, American Society for Engineering Education, Baltimore Convention Center, MD, June 25-28, 2023. Paper ID #39333, pp. 1-19.
Wible, S. (2022). Empathy. In J.C.K. Tham (ed.) Keywords in design thinking: A lexical primer for technical communicators & designers, University Press of Colorado, Denver, Colorado 80202. https://doi.org/10.37514/TPC-B.2022.1725
Zande, R.V. (2011). Design education supports social responsibility and the economy, *Arts Education Policy Review*, 112, 26–34. DOI: 10.1080/10632913.2011.518123
Zervoudi, E.K. (2019). Fourth industrial revolution: Opportunities, challenges, and proposed policies. In A. Grau & Z. Wang (eds.), Industrial Robotics, IntechOpen. doi: 10.5772/intechopen.90412
Zhongbin, Z. (2023). Integrating arts education system enhancing students' level of creativity: A case study in Beijing, China, *International Journal of Academic Research in Progressive Education and Development*, 12(2), 2462–2472. DOI:10.6007/IJARPED/v12-i2/17639

Design and Technology Education: An International Journal

28.2

# Preschool teachers' experiences of technological concepts in relation to everyday situations in the preschool

**Maria Svensson, University of Gothenburg, Sweden**
**Jonna Larsson, University of Gothenburg, Sweden**
**Ann-Marie von Otter, University of Gothenburg, Sweden**
**Helena Sagar, Municipality of Kungsbacka, Sweden**
**Pia Williams, University of Gothenburg, Sweden**

## Abstract
Communicating technological concepts in preschool is of vital importance for developing the quality of the technology teaching practice and children's language skills within the content area. The aim of this study is to describe how preschool teachers discern technology in relation to everyday situations in preschool. The study is part of a larger practice-based research and development project focusing on language development and technology teaching practice in preschool, while simultaneously developing and trying a collaborative model between preschool teachers and researchers. The empirical data for this study is generated by semi-structured interviews with preschool teachers. Data analysis employs a phenomenographic approach. Focus is directed towards how preschool teachers experience technological concepts in everyday situations in preschool. The findings include four qualitatively different ways of experiencing technology; *exploring techniques; exploring techniques using artefacts*; *exploring artefacts as technology* and *developing constructions using artefacts*.

## Keywords
preschool education, technology teaching practice, techniques, language development, phenomenography

## Introduction
Technology as content knowledge in early childhood education is an emerging field of research that has gained increasing attention, both nationally and internationally. Studies in relation to technology show that preschool teachers' content knowledge, along with their pedagogical knowledge to approach different parts of technology, is of vital importance for teaching in preschool (Sundqvist, 2016; Turja et al., 2009). A deeper understanding of the content knowledge can contribute to preschool teachers' development of capabilities and a more confident attitude towards teaching technology. Consequently, this may contribute to higher quality through an increase the number of teaching opportunities, extend the pedagogical experiences in approaching children's questions about technology, and thereby further develop the teachers' content knowledge. However, research shows that preschool teachers often lack in-depth understanding of technology as a content in the preschool context (Sundqvist & Nilsson, 2018; Sundqvist et al., 2015). This might add uncertainty among the preschool teachers regarding using and teaching adequate technological concepts, which, in turn, may have negative impact on their ability and motivation to create activities for children to learn and

discover technology (Thorshag & Holmqvist, 2018). Furthermore, it has been shown (Larsson, 2018) that scientific concepts need to be explicit within preschool activities to raise children's awareness of such concepts.

Dialogue and communication about technology between children and preschool teachers in varied situations, has proven to be important for high quality teaching (Fox-Turnbull, 2010; Larssson, 2018; Svensson, et. al., 2019). This requires good knowledge by the preschool teacher of relevant technological concepts. A high-quality preschool teaching practice is characterized by preschool teachers' competence to create conditions for children's learning and to clarify and communicate an object of learning (Brostrøm & Veijleskov, 2009; Marton & Booth, 1997). Teaching in preschool includes supporting all children's learning experiences by relating and responding to children in dialogue, developing child-focused strategies, and to challenge children's thinking while uniting play, care and education (Sylva et al., 2010; Williams & Sheridan, 2018). Preschool teachers' content knowledge and their pedagogical knowledge are crucial for their possibilities to develop, plan and provide a high-quality technology teaching practice.

The aim of this article is to describe how preschool teachers discern technology in relation their work with children in preschool with focus on their experiences of technological concepts in relation to everyday situations in preschool.

## Technology in Preschool

Research points to the importance of utilizing children's previous experiences in technology and technological concepts in the teaching practice (Mawson, 2013), as a base for children to create new knowledge. Mawson's (2013) showed that preschool children, who were exposed to technology education developed an awareness of and ability to use technological processes, establishing a purpose, planning and collecting appropriate resources and competently using tools and materials to achieve their desired outcome. To achieve this awareness and ability, preschool teachers play a central role which have been concluded in previous studies (e.g., Broström et al., 2015; Sundqvist & Nilsson, 2018). Preschool teachers' knowledge about the specific content and what learning of that content entail is of great importance for enabling children's learning. In relation to contents in the subject technology, studies have shown that this is a challenge, mainly because many preschool teachers lack sufficient knowledge both regarding the subject matter and regarding how to teach it in the preschool setting (Lillvist et al., 2014; Hellberg & Elvstrand, 2013; Sheridan et al., 2011; Sundqvist et al., 2015).

In a study by Svensson, et. al. (2019), they conclude that of great importance for children's opportunities to develop new knowledge in technology are preschool teachers understanding of the subject technology as well as children's previous experiences with technology. The study showed that when preschool children worked with the technology process, contextualized by a fairy tale, the children used sketches and experiences from everyday life to communicate technological ideas and solutions. The importance of children's past experiences and the concepts which they already had an understanding of became visible when they encountered a (for them) new technology content. In addition, the preschool teachers' uncertainty about technology as a field of knowledge and relevant technological concepts were shown to have impact on the quality support which they were able to give the children in their processes of learning technology and technological concepts.

Preschool teachers support of the children's reflections and reasoning, and communicating technological concepts in play and other everyday situations with learning opportunities in the preschool has also shown to have impact on their understanding of technology (see e.g., Axell, 2013; Stables, 1997; Turja et al., 2009). The difficulty of capturing an 'in-depth' understanding depends, among other things, on preschool teachers' and children's language use, and preschool teachers' content knowledge and pedagogical knowledge in discussing and developing technological solutions together with children. The preschool teacher needs to be aware of critical aspects of the content and their own use of language as well as the fact that the children have varying experiences of technology and might need different support to use words and technological concepts to think, understand and communicate technology (Turja et al., 2009). Children learn to use social- and content specific language by communicating in various contexts; namely, the functions of the language are linked to social practices, interests, norms, and values (Gee, 2014). In a preschool context, teaching is a matter of consciously communicating, leading, challenging and directing children's attention towards a specific content (Jonsson, 2013; Jonsson et al., 2017; Larsson, 2016). To be able to interact and communicate around a content area such as technology, children need access to the language used in the specific discourse (Barton, 2007). When children practice with different tools and models in technology it enables them to develop their language at the same time as they explore and discover phenomena in the world around them, granted that the preschool teachers introduce relevant technological concepts into the children's play and other everyday situations (Fleer, 2000; Turja et al., 2009). Essential for enabling learning is the way preschool teachers organize activities and support children with material and concepts that create a context in which they build on children's prior experiences and challenge them to understand things in new ways (Larsson, 2016).

**Technology in Swedish Preschool Context**

The present study is conducted in Sweden where the recent preschool curriculum (National Agency for Education, 2018) points out that the early childhood education should challenge and stimulate every child's development of *language*, mathematics, *technology* and science. Exploration, curiosity, and a desire to play should be the foundation of this education. It should be characterised by care, development and learning coming together to form an entity. (National Agency for Education, 2018, p. 14). Compared to the previous curriculum (National Agency for Education, 1998), the intention is to make the early childhood education more oriented towards learning and a teaching practice of high quality.

An important activity for children's learning in Swedish preschool is play. Play provides children with the opportunity to use experiences and knowledge to get involved in technological activities such as building, constructing and exploring. Children explore technology through construction work with toys and try out their own ideas for mechanical solutions in playful ways (Bjurulf, 2013). Building and constructing can include anything from building huts to simple construction tools, and a variety of materials is used depending on the outcome of the activity as an object. How children handle challenges in the building and constructing activities depends on how they act and make decisions based on their volition (Mitcham, 1994). Volition is defined as the process of making and acting on decisions. Even though construction technology has a long tradition in preschool (Bjurulf 2013), knowledge of technology and the technological concepts used need to be discerned and highlighted for the children. In relation to technical volition Thorshag and Holmqvist (2018) show that children viewed the constructing material in different ways, either seeing the material as foreground or regarding it as pieces in a construction. Some children expressed volition for using the material to make a construction while others showed volition for exploring the material as such.

Early childhood education in Sweden should create opportunities for children to develop creativity as well as the ability to discover and develop technological solutions in everyday life. Furthermore, the physical learning environment in preschool is required to provide materials which invite children to build, create and construct with the help of different techniques, materials and tools (National Agency for Education, 2018). In high-quality technology education, the children's experimentation is supported by preschool teachers' interactions and dialogue with the children around different solutions and improvements, while using technological concepts. Therefore, preschool teachers need to develop their understanding of, and language for technology to identify, discover and make visible new technological solutions together with the children.

**Technology Knowledge**

Technology as a field of knowledge and concept has a central position in this project. Discussions about and understandings of technology inspires and guides the work. Technology is a wide-ranging concept and can be used to represent for example methods, systems, things, processes, or actions (Kline, 2003), thus, it is a concept that can be difficult to grasp, especially since there is not one specific definition, despite all the attempts, which have been made. As a way to "unpack" technology as a concept, Kline (2003) describes four different ways in which technology may be understood: 1) artefacts – non-natural objects, manufactured by humans, 2) sociotechnical systems of manufacture – all the elements needed to manufacture an artefact, the complete system such as input, people, resources, process, economy etc., 3) knowledge, techniques , know-how or methodology – information, skills, processes, and procedures for accomplishing a task, and 4) sociotechnical systems of use – using combinations of artefacts and people to accomplish tasks that humans cannot perform unaided by such systems. Another way of describing technology, widely used in the Swedish technology education, are Mitcham's (1994) fourfold characterization of technology (Fig. 1), *volition*, *knowledge*, *actions* and *objects*, as an orientation towards action aiming at a particular outcome. *Knowledge* relates to the information needed to carry out the activity. *Volition* relates to the children's own willingness and intention to design products, processes and systems. Technological *activities* are carried out to produce something or use technological solutions. *Objects* are the artifacts used or created in the activity. One conclusion of this is that technological knowledge and will, with their origins in humans, give rise to technological activities expressed as concrete technological objects.

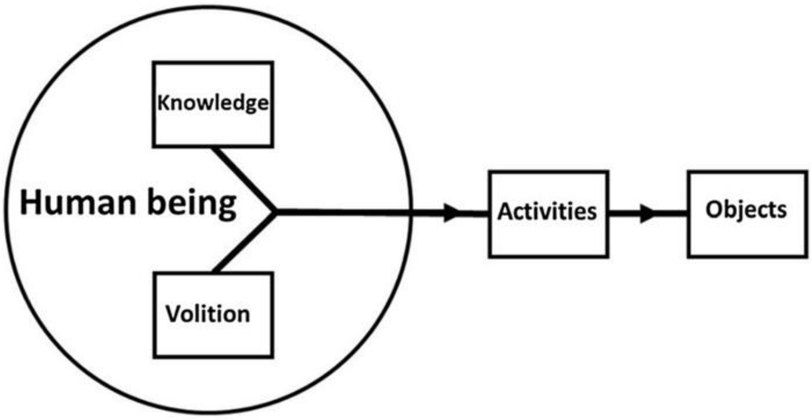



***Fig. 1. The four manifestations of technology (from Mitcham 1994, p. 160)***

In relation to earlier research, we want to describe preschool teachers experiences of technological concepts in relation to everyday situations in preschool.

## Theoretical Framework

The theoretical framework of this study is based on phenomenography as a qualitative research approach (Marton & Booth, 1997). Phenomenography offers opportunities to investigate research questions concerning ways of understanding specific phenomenon, such as technological concepts in relation to different everyday situations in the preschool. One fundamental assumption in the phenomenographic approach is that there are qualitatively different ways of understanding a particular phenomenon or aspect of the world (Marton & Booth, 1997). Some of these ways to understand can be argued to be more powerful than others when acting in the world. The focus in a phenomenographic study is the empirical search for qualitative differences in the collective experience of the phenomenon. The essence of the phenomenographic approach as taking a non-dualistic, qualitative, second-order perspective where the aim is to identify key aspects (i.e., critical aspects) in the variation of learners' collective experience of a phenomenon, that results in a set of hierarchical categories of descriptions that are internally related (Cederqvist, 2021; Trigwell, 2006). In this study we describe how preschool teachers discern technology in relation their work with children in preschool with focus on their experiences of technological concepts in relation to everyday situations in preschool. From this theoretical perspective, the phenomenon of technological concepts that preschool teachers encounter in various situations and in different preschool activities are modified and developed through the situations in which the phenomena are experienced.

## Method

This study is based on a collaborative practice-based project about teaching technology in preschool. The project as a whole is firmly rooted in the challenges and needs of the profession, as it is based on preschool teachers' own questions about technology and their use of language for teaching technology in their specific preschool practices. The preschool teachers initiated the project by contacting researchers in the field at the nearby university. The empirical data is produced by semi-structured and open-ended interviews with twelve preschool teachers in two Swedish preschools; six preschool teachers from each preschool. The preschool teachers have between 4.5 to 36 years of experience in the profession. Two researchers participated in each interview; one conducted the interview and the other one listened and supported with the technical equipment. All interviews were audio recorded and transcribed verbatim by the researchers.

The interviews followed a piloted interview guide, which was generated in collaboration between the researchers and piloted on an external preschool teacher. To gain a shared experience between the preschool teacher and the researchers, each teacher was asked to bring a photo from an everyday situation in their preschool environment, which they considered to be in some way related to technology. The situations ranged from outdoor to indoor activities and involved children from one to five years of age. The interview started with a discussion around the technology experienced in the chosen situation of the photo. Examples of questions that the interview started with are: Why did you choose the situation? Is it a common situation? How do you describe technology in relation to the situation? Can you give examples of more situations which include technology?

**Analysis**

The phenomenographic analytical approach to research was used to discern variations in the preschool teachers' experiences of technology in everyday situations in preschool. Thus, the analytical approach elucidated various aspects of learning and understanding in the educational environment (Marton, 2014; Marton & Booth, 1997). The results are generated in the empirical data. The research outcome is a set of categories, which describe qualitatively different ways of experiencing a phenomenon, here how technology is experienced in everyday situations in preschool. These categories are logically interconnected in both structure and meaning. These categories do not describe how the specific individual perceive the phenomenon, rather as a set, they indicate potential ways in which individuals can perceive the phenomenon.

The analytical process was conducted in several steps (e.g., Marton & Booth, 1997). Initially the interviews are transcribed verbatim and is read repeatedly as a whole by the researchers to become familiar with it as a collective entity, following a typical phenomenographic approach to data analysis (see e.g., Cederqvist, 2021; Svensson, 2011). The analysis continued with a focus on and systematic identification of the parts of the interviews that described technology in everyday situations in different preschool activities. The relevant parts of individual interviews are seen as meaning units. The collection of empirical material was in this way transformed from a set of full-length interviews to a set of focused units of interview excerpts. These manageable units could then be compared and contrasted to each other, which consequently proposed rich opportunities to delve into how the preschool teachers described the situations and connected them to technology. At this stage, meaningful variation began to emerge between different subsets of the interview excerpts. These tentative subsets were carefully described in terms of their differences, and subsequently in terms of their defining qualities.

Since no single excerpt fully captures one category, several quotations from all interviews have been chosen to elucidate and support the main thrust of the categories, especially in terms of the meaning and structure of the understanding of the technology that preschool teachers associate with an everyday situation in preschool. All interviews are coded with a letter and a number, indicated in parentheses after each excerpt.

**Ethical considerations**

The design of the study follows the ethical requirements set by the Swedish Research Council (2017). The preschool teachers and the children's caregivers were informed about the purpose of the project, the requirement for anonymity and that the participants could at any time refrain from participating in the research. Written consents from preschool teachers and caregivers to the children participating in the study was collected. The photos used during the interview are the preschool teachers' own photos, which they have given us permission to use for research purposes. The photos have been anonymized and only the activity is in focus. Although it is the preschool teachers who are in focus in this study, a research study in a preschool context always includes children; hence require additional responsibility from us as researchers to create a safe context for everyone involved. Consequently, ethical considerations are discussed throughout the research process, as it is impossible to know in advance which ethical issues may arise (Coady, 2010; Larsson et al., 2019). All data was anonymized, including the names of preschools and people, coded and kept separate from the original data. The interviews and other documentation related to the project is stored at the University of Gothenburg.

## Results

The analysis resulted in four, qualitatively distinct categories: a) Exploring techniques, b) Exploring techniques using artefacts, c) Exploring artefacts as technology and d) Developing constructions using artefacts. In these categories there are differences in preschool teachers experiences of artifacts as well as of technology as a skill or as a way of solving problems.

Technology is often related to artifacts (De Vries, 2016; Kroes & Meijers, 2006; Säljö, 2013). Artifacts could in the most obvious way of thinking, be understood as human-made objects. That makes them different from natural objects, which are not human-made. Artifacts as human-made objects have a certain function and have been made because of that. To be a technological artifact, the entity needs to have a function, but also to be a physical object (Frederik, et. al., 2011). Descriptions of technology varies according to techniques and/or technology. In this study we understand techniques as a particular way of doing things, where you need to learn a special skill, for example using paintbrushes in a specific way to create a certain pattern. We define technology as the knowledge needed for solving a problem or meeting a desire that someone has, for example developing an artefact that could be used to open a can.

Below, the categories are defined and illustrated by the interview excerpts. Each excerpt ends with an indication in brackets of the preschool X and Z and the preschool teacher as a number. The photos presented are the ones that the preschool teachers brought to the interview as examples of a technology related to an everyday situation in their preschool environment.

**A. Exploring techniques**

In this category, the preschool teachers relate technology to exploring techniques, in the sense that they as preschool teachers observe situations where children use their body to investigate objects, events and activities in the preschool environment. They give as example the best way to climb a chair, how to get the swing to move and how to roll down the hill as fast as possible, which could be expressed as an investigation of a natural phenomenon such as speed and friction. The photo (1) exemplifies how the children roll down a small hill located on the preschool playground.

> *Well, it's technology almost all the time, swinging and rolling on slopes and so, yes, much is technology. (X5)*

> *...get up on a chair, how do I lift my leg, arm, so that I can get up on the chair ... put on clothes, pull up a zipper, open a door handle, push down the handle. (Z3)*

> *This is us on the hill [pointing at the photo] and I had an idea that we can scroll down the hill and compare ... Do you have any special technique? Is it faster if you roll in some special way? How does it feel if you scroll things up the hill, …, making a contrast? (X1)*

***Photo 1. Children using their bodies to investigate the fastest way to scroll down a hill***

In the category of exploring techniques, the preschool teachers' understanding of technology is connected to and represents a skill. When they are asked about technological concepts that they relate to these situations, they mention the skill in terms of verbs like; to roll, to slow down, to overturn and to get stuck. In this category, artefacts, if present, are in the background of preschool teachers' awareness and the skills used to solve the problem, for example climbing the chair, is in the foreground. In this category the preschool teachers describe techniques that occur in everyday situations.

**B. Exploring techniques using artefacts**

This category exemplifies how the preschool teachers relate technology to various situations in which children use artefacts such as brushes, balloons and magnetic building blocks in order to explore and learn about different techniques. In the following excerpts the preschool teachers describe technology in two different situations where children paint (photos 2 and 3)

> *I probably think more about technology when it comes to mixing color [looking at a photo 2, where the children are painting with different paintbrushes], in my mind, ... not that we used technology as a tool but more just the technique of mixing color, that's where I'm in my mind. (X6).*

***Photo 2. Children painting using brushes***

> *Yes, but I think of this [pointing at the photo 3, with children using balloons as a tool when painting] with push and force depending on how hard you push, how big the imprint and technique of mixing colors and what happens then and what happens if I spin the balloon and so on. (X2)*

***Photo 3. Children painting using balloons***

Artefacts and techniques are also in the foreground in everyday situations as we can see in the first excerpt (Z1) below, where the children try an old projector, but also in the daily meal situation exemplified in the second excerpt. (X3)

> *We have an old overhead (…) but as the children use a lot and project on the wall because we have no other portable projector and so we have (…) this child who suddenly put the tangram pieces on the overhead completely spontaneously and then discovered when it was projected that it became a new color. I thought it was just a cool moment, it was just like completely spontaneous of her nothing that we had planned. (Z1)*

*...to eat, to share their food, to get to the technique with a knife and fork, that I can put up food with a fork, catch food with the tips of the fork... (X3)*

There are indications of the preschool teacher's emerging awareness about a difference between technological artefacts and techniques, illustrated in the following excerpt:

*In another situation, perhaps more planned in the painting room, where brushes are used as a technological aid or a corrugated board or something to draw a color. You can use technology and it becomes a mixture of what can be linked together, what happens as technology and as technological tools for mixing color ...(Z6)*

In comparison with category A, the excerpts in category B indicate that the preschool teachers' express an understanding of technology as something more than techniques in which the body is used to investigate natural phenomena; artefacts are in the foreground of preschool teachers' awareness and seem to have an important role in the situation. The chosen situations are planned in such a way that the preschool teachers have prepared with artefacts for the children to use.

**C. Exploring artefacts as technology**

Excerpts in this category indicate that technology situations in preschool are related to exploring technological artefacts, rather than to techniques. The preschool teachers' expressions put focus on the function of the artefacts and how the children can investigate these functions. In the excerpts, two situations are highlighted. In the first (photo 4), a child is holding a fruit bowl and the preschool teacher describes the bowl as an artefact with a function; the function of holding items. In the second and third excerpt the preschool teacher describes how everyday situations contribute to opportunities for children to explore and play with artefacts and try to understand how they work.

*Mm, yes, because I think, it is a little technology just to be able to carry around and offer the fruit in a bowl, so that you do not drop the fruit, something like that. It's a little unclear to me what to think about technology. (X5)*

***Photo 4. Children carry around and offer fruits from a bowl***

*There is a lot of technology that young children do. It can be a button, a lamp button, it is really fun to turn on and off, on and off, it can be done twenty times. They roll cars,* *they drive them on different things. They use the material in different ways on the elements and on the window frames and so on. (Z2)*

*It's technology, everyday technology It's technology, everyday technology, to open and close doors, light buttons are very fun when the children understand this and even at the tap you could stand for a whole day. It's like everyday technology for the little kids, yes in all situations it comes in if you think about it. (Z4)*

Compared to category A and B, the excerpts from the preschool teachers in category C includes a movement from understanding technology situations as techniques, to an understanding of technology as the development, use and exploration of artefacts for specific functions.

**D. Developing constructions using artefacts**

To build, develop and construct an artefact or a system is phrased by some of the preschool teachers as involving technology. The excerpts below illustrate how the preschool teachers express their understanding of the possibilities for children to learn about principles for constructing, when using specific materials/equipment for example magnetic building blocks. Photo 5 illustrates the children's play with magnetic building blocks and the various solutions and constructions the play with the artifacts can give rise to.

The preschool teacher expresses that:

*Yes, because they love to build with these magnets, [magnetic building blocks]. They build so many different things, ... roads, different ... platforms for airplanes ... animals, they have built turtles. Everything is possible to build with them.  They learn that the building must be stable (hesitates), yes, and that, they have to have a foundation and sometimes they need a drawing. (Z5)*

Another preschool teacher said that*:*

*you can develop it a lot, especially with these magnets [magnetic building blocks] in how they build oh ..., you can have a foundation on which it can stand and if it falls you can talk to the children about how to make it more stable and so on. So, there's a lot to work on with technology around this. (Z1)*

***Photo 5. Children using magnetic building blocks to make constructions***

In this category the preschool teachers associate to a variety of technological concepts, for example platform, stability and joining. The most significant difference from the previous categories is that in these excerpts the preschool teachers relate technology to artefacts and systems that can be used for children's learning and development, in a problem-solving activity within the area of technology. By communicating possible ways of constructing in children's play with artefacts, the preschool teachers' express that they see a multitude of teaching entrances and to make the children aware about how different techniques can contribute to constructing. In that way we interpret a potential for relating technology to problem solving activities where children investigate, construct, explore and evaluate artefacts and systems.

## Discussion

In this study focus is directed towards the technology that preschool teachers discern in everyday situations in preschool. The findings emphasize four different ways of experience technological concepts, described as *exploring techniques*; *exploring techniques using artefacts*; *exploring artefacts as technology* and *developing constructions using artefacts*. The preschool teachers talk about technology situations and concepts, and they give a rich variety of examples ranging from exploring techniques to developing constructions using artefacts. In the first category (A), exploring techniques, technology is above all connected to the development of a skill, while in the last category (D), developing constructions using artefacts, is technology related to problem solving activities, embracing, and focusing both constructing, exploring, and investigating artefacts.

The results highlight the variation in which preschool teachers express their understanding of technology in everyday situations in different preschool activities. In their talk about technology, the preschool teachers put different aspects in the foreground, ranging from a focus on techniques as a skill or method, to development and construction with technological artefacts. When techniques are in the foreground as in category A, only a limited part of technology, as a subject matter of knowledge appears. This category does not connect to any physical representation like an artefact and is in that way not related to technology knowledge as described by Mitcham (1994) or Kline (2003). As we move through the categories, there is a variation from describing technology as exploring a technique, towards an integration of artefacts which connects to Kline's (2003) understanding of artefacts as non-natural objects manufactured by humans. In category D, the preschool teachers use artefacts in systems for children's knowledge development and express an awareness of the role of technological concepts when teaching technology in preschool. The last category indicates a more developed understanding of technology in relation to everyday preschool activities and can be related to Mitcham's (1994) fourfold characterization of technology as knowledge, volition, action, and object.

In the Swedish preschool education, play holds a central position and is the foundation for children's development, learning and well-being. It is interesting to note how the preschool teachers provide examples of how they identify technological concepts present in children's play. In playful activities such as turning a light on and off, rolling down a grassy slope, driving a toy car on different surfaces, or playing with magnetic building blocks, solutions and constructions are exposed to solve upcoming issues with various artifacts (Bjurulf, 2013). However, as previous research highlight (e.g., Thorshag & Holmqvist 2018; Williams & Sheridan, 2018), it is of vital importance that all children are supported to discover technology and given rich opportunities to use technological concepts in the preschools' everyday situations. Not only the children actively exploring technology, but also those who are not, should be challenged in their learning by the preschool teacher. Being able to communicate and put words on what is happening in an activity is an important aspect of play and learning, regardless which subject area it is about and contributes to equal opportunities in the preschool education. However, this requires that the preschool teachers have sufficient content and pedagogical knowledge, are creative and play with language, and make use of different opportunities to approach aspects of technology in various forms (Sundqvist, 2016; Turja et al., 2009).

We interpret that the results from this study have implications on what preschool teachers need to develop their technology knowledge about, the difference between technique and technology, the role of artefacts and the problem solving in relation to artefacts. Being aware of different aspects of technology means understanding technology in a more complex and powerful way (Marton & Booth, 1997), which in turn gives the preschool teacher opportunities to talk about, reflect on and teach technology more nuanced. Thus, the results strengthen the importance of preschool teachers' ability to relate technology situations to artefacts and systems, as seen in category D, to child related activities where the children play, investigate, construct, explore and evaluate.

This result can be related to research (e.g., Turja et. al., 2009; Sundqvist & Nilsson, 2018) underlining that children need guidance from well-informed, supportive and challenging preschool teachers so that the children can get acquainted with different materials to develop skills regarding designing, building and constructing. Important teaching competences includes required content knowledge, related to what is reasonable to expect from children in preschool ages, together with preschool teachers' pedagogical knowledge. Furthermore, content-specific concepts are essential when communicating a content, if to raise children's awareness of such concepts (Larsson, 2018). The results also highlight that preschool teachers need to have knowledge about and consider the children's previous experiences, to deepen and expand children's understanding and meaning making within the specific content area.

## Acknowledgements

This work was funded by the Swedish Government through a project which aims to encourage and support practice-based research in collaboration with preschools and compulsory schools (https://www.ulfavtal.se/?languageId=1)

## References

Axell, C. (2013). *Teknikundervisningen i förskolan: En internationell utblick* [Technology teaching in preschool: An international outlook]. Forum för ämnesdidaktik, Linköpings universitet.

Barton, D. (2007). *Literacy: an introduction to the ecology of written language*. Malden MA: Blackwell.

Bjurulf, V. (2013). *Teknikdidaktik i Förskolan*. [Technology Education in Pre-school.] Studentlitteratur.

Broström, S., Sandberg, A., Johansson, I., Margetts, K., Nyland, B., Frøkjaer, T., et al. (2015). Preschool teachers' views on children's learning: An international perspective. *Early Child Development and Care, 185*(5), 824–847.

Brostrøm, S., & H. Veijleskov. (2009). *Didaktik i børnehaven: Planer, principer og praksis* [Didactics in Preschool: Plans, Principles and Practice]. Dafolo.

Cederqvist, A. M. (2021). *Seeing the parts, understanding the whole-A technology education perspective on teaching and learning in processes of analysing and designing programmed technological solutions*. Göteborg: Acta Universitatis Gothoburgensis.

Coady, M. (2010). Ethics in early childhood research. In *Doing Early Childhood Research. International perspectives in theory and practice.* G. MacNaughton, S.S. Rolfe., & I. Siraj-Blatchford (Eds.). Open University Press.

Fleer, M. (2000). Interactive technology: Can children construct their own technological design briefs? *Research in Science Education*, *30*, 241-253.

Frederik, I., Sonneveld, W., & de Vries, M. J. (2011). Teaching and learning the nature of technical artifacts. *International journal of technology and design education*, *21*(3), 277-290.

Fox-Turnbull, W. (2010). The role of conversation in technology education. *Design and Technology Education: An International Journal*, 15(*1*).

Gee. J. P. (2014). Decontextualized Language: A Problem, Not a Solution. *International Multilingual Research Journal, 8:*1, 9-23.

Hellberg, K., & Elvstrand, H. (2013). Pedagogers tankar om teknik i förskolan. *Venue*, (2), 1–5. https://doi.org/10.3384/venue.2001-788X.13213

Jonsson, A. (2013). *Att skapa läroplan för de yngsta barnen i förskolan. Barns perspektiv och nuets didaktik*. Göteborg: Acta Universitatis Gothoburgensis.

Jonsson, A., Williams, P., & Pramling Samuelsson, I. (2017). Undervisningsbegreppet och dess innebörder uttryckta av förskolans lärare. *Forskning om undervisning och lärande*, 5(*1*), 90-109.

Kline, S. J. (2003). What is technology. In R.Sharff & V. Dusek (Eds.), *Philosophy of technology: the technological condition: an anthology*, 210-212. Oxford: Blackwell Publishing.

Kroes, P., & Meijers, A. (2006). The dual nature of technical artefacts. *Studies in History and Philosophy of Science*, 37(1), 1-4.

Larsson, J. (2016). *När fysik blir lärområde i förskolan*. [Doctoral thesis .When physics becomes an area of study in preschool]. Göteborg: Acta universitatis Gothoburgensis.

Larsson, J. (2018). Grasping the essence of a science activity by using a model of pedagogical reasoning and action. *Education 3-13. International Journal of Primary, Elementary and Early Years Education, 46*(7), 770-781.

Larsson, J., Williams, P., & Zetterqvist, A. (2019). The challenge of conducting ethical research in preschool. *Early Child Development and Care, 191,* 4, 511-519. https://doi.org/10.1080/03004430.2019.1625897.

Lillvist, A., Sandberg, A., Sheridan, S., & Williams, P. (2014). Preschool teacher competence viewed from the perspective of students in early childhood teacher education. *Journal of Education for Teaching, 40*(1), 3–19. doi:10.1080/02607476.2013.864014.

National Agency for Education. (1998). Curriculum for the Preschool Lpfö1998. *The Swedish National Agency for Education*. Stockholm: Skolverket

National Agency for Education. (2018). Curriculum for the Preschool Lpfö2018. *The Swedish National Agency for Education*. Stockholm: Skolverket

Marton, F. (2014). *Necessary conditions of learning*. Routledge.

Marton, F., & Booth, S. A. (1997). *Learning and awareness*. Psychology press.

Mawson, B. (2013). Emergent technological literacy: what do children bring to school? *International Journal of Technology and Design Education*, 23 (*2*), 443-453).

Mitcham, C. (1994). *Thinking through Technology*. The University of Chicago Press.
Sheridan, S., Williams, P., Sandberg, A., & Vuorinen, T. (2011). Preschool teaching in Sweden—A Profession in change. *Educational Research, 53*(4), 415–437.
Stables, K. (1997). Critical Issues to Consider When Introducing Technology Education into the Curriculum of Young Learners. *International Journal of Technology Education*. 8 (*2*).
Sundqvist, P. (2016). *Teknik i förskolan är inte något nytt, men idag är vi mera medvetna om vad vi kallar teknik: Personalens beskrivningar av teknik som innehållsområde i förskolan* [Doctoral thesis. Technology in preschool is not new, but today we are more aware of what we call technology: Staff descriptions of technology as a content area in preschool]. Mälardalen University.
Sundqvist, P., & Nilsson, T. (2018). Technology education in preschool: providing opportunities for children to use artifacts and to create. *International Journal of Technology Design Education, 28,* 29-51.
Sundqvist, P., Nilsson, T., & Gustafsson, P. (2015). *The Purpose of Technology Education in Preschool: Swedish Preschool Staff's Descriptions*. In Conference PATT 29: Plurality and complementarity of approaches in design and technology education, 7-10 april 2015, Palais du Pharo, Marseille, France (pp. 390-396).
Svensson, M. (2011). *Att urskilja tekniska system: didaktiska dimensioner i grundskolan*. [Doctoral thesis. Discerning technological systems – pedagogical possibilities in compulsory school]. Linköping University Electronic Press.
Svensson, M., Dahlbäck, K., & von Otter, A. M. (2019). När sagans problem utmanar och inspirerar-en studie av förskolebarns arbete med tekniska lösningar [When a problem in a fairy tale challenge and inspire-a study of preschool children's work on technological solutions.] *Nordic Studies in Science Education*, *15*(1), 79-96.
Swedish Research Council (2017). *Good research practice*. Vetenskapsrådet, VR1710, https://www.vr.se/download/18.5639980c162791bbfe697882/1555334908942/Good-Research-Practice_VR_2017.pdf (2020-03-31)
Sylva, K., Melhuish, E., Sammons, P., Siraj-Blatchford, I., & Taggart, B. (Eds.). (2010). *Early childhood matters: Evidence from the effective pre-school and primary education project*. Routledge.
Säljö, R. (2013). Thinking with and through artifacts: The role of psychological tools and physical artifacts in human learning and cognition. In *Learning relationships in the classroom* (pp. 54-66). Routledge.
Thorshag, K., & Holmqvist, M. (2018). Pre-school children's expressed technological volition during construction play. *International Journal of Technology and Design Education*, 1-12.
Trigwell, K. (2006). Phenomenography: An approach to research in geography education. *Journal of Geography in Higher Education, 30*(2), 367-372.
Turja, L., Endepohls-Ulpe, M., & Chatoney, M. (2009). A conceptual framework for developing the curriculum and delivery of technology education in early childhood. *International Journal of Technology and Design Education*, 19, 353-365.
De Vries, M. J. (2016). *Teaching about technology: An introduction to the philosophy of technology for non-philosophers*. Springer.
Williams, P., & Sheridan, S. (2018). Förskollärarkompetens - skärningspunkt I undervisningens kvalitet [Preschool teacher competence - the point of intersection of quality in teaching]. *Barn. Forskning om Barn og Barndom i Norden, 36*(3-4), 127-136.

# Exploring Inclusive Design and Digital Humanities: Enabling Bilingual Digital Narratives for Deaf Children

**Cristina Portugal, São Paulo State University, Brazil**
**Marcio Guimarães, Federal University of Maranhão, Brazil**
**Monica Moura, São Paulo State University, Brazil**
**Jose Carlos Magro Junior, São Paulo State University, Brazil**

## Abstract
The collaboration between designers and digital humanists has indeed gained increasing significance in crafting effective projects, with design serving as a centralizing force in the realm of digital humanities by establishing interfaces for individuals to engage with technological resources. Therefore, design's methodological practices, encompassing various research and experiential facets, play a pivotal role in enhancing the usability and accessibility of digital resources within the social sphere. This study aims to expand the discourse on the characteristics and potential of the interplay between inclusive design and digital humanities practices, with a specific focus on the development of bilingual digital narratives (utilizing Brazilian Sign Language and Portuguese). The research adopts a collaborative, qualitative approach, encompassing processes of evaluation, validation, and enhancement. Digital visual narratives are presented as a facilitating tool for integrating LIBRAS and Portuguese, thereby aiding in language acquisition for deaf children. The article contributes to the discussion of the humanistic approach to design, emphasizing the values of empathy, ethics, and social responsibility in the creation of inclusive and accessible projects.

## Keywords
Design, technology, education, digital narrative, hearing impairment

## Introduction
This paper offers a brief reflection on the correlation between design and digital humanities, a theme that has been driving our discussions and research planning in the field of inclusive design over recent years. The results presented here stem from an interdisciplinary research project that bridges the realms of design and digital humanities. This project's primary goal is to create bilingual digital narratives, encompassing Brazilian Sign Language (LIBRAS) and Portuguese, and catering to both deaf and hearing children.

The work carried out by Portugal (2017 to 2022) during the Productivity Research Scholarship - PQ/CNPq period provides a theoretical foundation for the research presented here. Furthermore, the research conducted during the postdoctoral fellowship at the School of Communication at the Royal College of Art (RCA) in London contributes to this article. This work resulted in the development of a series of books that meticulously present fundamental concepts, studies, and reference material related to design and its complex interaction with technology and other related domains, all in a pedagogical format. These concepts provide a solid foundation for digital humanities projects, as they involve designers deeply engaged in the symbolic representation of language and their crucial role in meaning construction.

The synergy between designers and digital humanists has assumed increasing significance in the creation of effective projects. Design functions as a central element for digital humanities by sculpting interfaces that enable individuals to interact seamlessly with technological resources. Consequently, design's contribution is substantial, given that its methodological practices encompass a spectrum of research and experiential facets that streamline the utilization of digital resources within the social sphere, rendering them more instinctive and accessible.

Aligned with this rationale, this article presents a contemplation of the intrinsic relationship shared by design and digital humanities. It delves into the language development in deaf children and introduces a project centered around visual digital narratives. These narratives serve as a facilitative medium that harmoniously blends two languages, LIBRAS and Portuguese, to aid in language acquisition among deaf children, thus fostering their inclusive integration into society.

## Interdisciplinarity between design and digital humanities

The relationship between the fields of design and humanities is of utmost importance for developing projects that address social, cultural, and technological needs. Collaborations between design and humanities can yield innovative and impactful solutions that reflect the complexity of society and human experiences. Moreover, the humanistic approach to design, emphasizing empathy, ethics, and social responsibility, can foster inclusion and diversity in the solutions designed. Through this interaction, projects can be tailored to meet the unique needs and expectations of users, while considering cultural values and meanings.

Authors such as Anne Burdick et al. (2012/2020), Johanna Drucker (2014), Jentery Sayers (2018), Cristina Portugal (2022), among others, advocate for collaboration between design and humanities as an opportunity to design solutions that address contemporary challenges and improve people's quality of life.

The significance of interdisciplinary approaches in design and digital humanities is underscored by the authors mentioned above. They argue that design should draw knowledge and skills from various fields, including computer science, cognitive psychology, media studies, literary theory, art history, and more. Therefore, the relationship between design and digital humanities is fundamental for developing technological solutions that consider the cultural and human dimensions inherent in technology interactions.

Burdick (2012) defines digital humanities as an interdisciplinary field that examines the intersection of technology and culture. It seeks to understand how digital technologies transform the forms of expression, production, and dissemination of knowledge and culture. This approach emphasizes the importance of a critical and reflective outlook that takes into account the social, cultural, political, and ethical dimensions involved in the production and utilization of digital technologies.

Similarly, just as the term "writing" encompasses a broad spectrum of activities, "design" encompasses a range of practices, from everyday tasks to highly specialized domains. Design, in the broader sense, encompasses various facets, from business strategies and "design thinking" methodologies to the "design sciences," including engineering and human-computer interaction, along with cultural criticism and provocative "critical design." Digital humanities projects closely align with communication, graphic, and visual designers who are concerned with the symbolic representation of language, the graphic expression of concepts, style, and identity.

Burdick (2012) asserts that design can collaborate with the field of digital humanities by bringing a practical and concrete approach to creating interfaces and interactions with digital technologies. Design should not be a mere superficial aesthetic layer on digital products but an integral part of the development process, capable of reflecting on the ethical, cultural, and social issues entwined in their creation. Furthermore, design can enhance the accessibility and comprehensibility of data and information for diverse audiences, crafting innovative solutions that consider user needs and perspectives.

Drucker (2014) adds to these ideas by highlighting how design can create more transparent and accessible interfaces for information, enhance the user experience when interacting with digital data, and communicate complex and abstract information in a clearer, more engaging way. Additionally, design plays a pivotal role in shaping the way information is created, organized, and presented, contributing to a more innovative and user-centric field of digital humanities.

According to Drucker (2014), most information visualizations are acts of interpretation presented visually, not mere representations of the world. Recognizing this, our task is threefold: to study information visualizations to understand their functioning, to question the familiar interfaces that have become habitual, and to consider how to visualize interpretation, serving a humanistic agenda.

The intersection between design and digital humanities is advocated by Portugal (2022), who posits that design should focus on creating tools and experiences that expand human capabilities in thinking, communication, collaboration, and creativity.

Furthermore, the author contends that design is inherently a cultural practice, and culture itself is profoundly influenced by technology. She posits that research in digital humanities offers a robust theoretical and methodological framework for comprehending how technology moulds culture and, reciprocally, how culture shapes technology. This comprehension holds paramount significance for interactive design, a field committed to crafting meaningful and transformative user experiences.

Within the realm of design, a pivotal discourse centers on the imperative of collaboration between designers and digital humanists. Equally critical is the infusion of critical and theoretical perspectives into design practices, enriching user experiences and advancing principles of inclusivity and accessibility in the digital era. Furthermore, the exploration of the application of emerging technologies, such as artificial intelligence and virtual reality, within the domain of digital humanities design, is a subject of paramount importance.

The methodologies embraced by design for the creation of accessible interfaces encompass several key approaches:

- User-centered design, characterized by the active engagement of users throughout the design process, ensuring their needs and experiences are integral considerations from inception.

- Inclusive design, which aspires to devise solutions that cater to the requirements of all users, irrespective of their abilities or limitations.
- Universal design, entailing the creation of solutions universally accessible to everyone, regardless of their abilities or limitations, without necessitating supplementary adaptations.

This article, in particular, will delve into the realm of inclusive design as an overarching approach. Inclusive design seeks to produce products, services, environments, and technologies universally usable by individuals, regardless of their physical, cognitive, or sensory capabilities. Its fundamental aspiration is the removal of barriers, championing accessibility and inclusion for individuals with disabilities and special needs. It vigilantly acknowledges individual disparities and endeavours to ensure parity in addressing the demands of all users. Inclusive design may additionally involve the active participation of individuals with disabilities in the design process, thus ensuring that their perspectives and requirements are conscientiously integrated from the outset.

To initiate the discussion on the interplay between design and digital humanities in crafting visual narratives to aid language acquisition for deaf children, we commence with a succinct examination of language development in children is presented below.

## A Brief Reflection on Language Development in Deaf Children

Understanding the social development of the human mind necessitates an exploration of the intricate relationship between thought and language during a child's intellectual development. Vygotsky (1987) proposed the analysis of this relationship in discrete units, culminating in the assertion that the word's meaning constitutes the fundamental unit of both thought and language. The significance of a word is pivotal in constructing a line of reasoning, and language provides the means to articulate it. This relationship between thought and word is reciprocal, with words serving thoughts and thoughts informing words. The developmental journey of thought and language occurs at distinct paces, permitting the gradual evolution of word meanings in response to experiences and varying situations throughout the learning process. As a child progresses, they begin by associating two or three words with the tangible attributes of an object, progressively distinguishing the object from its properties.

The pre-linguistic phase corresponds to a stage in cognitive development, analogous to the pre-intellectual phase in language development. In the pre-linguistic phase, children lack the linguistic means to convey their thoughts but communicate their needs through affective expressions, such as crying or pointing. Upon acquiring language, their thinking matures, enabling them to consciously differentiate meanings and attribute them precisely to express their thoughts.

Language serves as a tool for individuals to imbue meaning into objects, orient themselves in time and space, and establish their role as agents in society. Language offers diverse modes of expression, encompassing thought, oral and gestural speech, and writing. While oral speech adheres to its unique rules and norms, it is in writing that language achieves its most intricate and comprehensive structure. Thought serves as the precursor to both spoken and written language, yet it can remain confined to the inner realm, inaccessible to the external world.

In Vygotsky's research involving groups of children, he observed that the gestures children employ when expressing themselves constitute the initial indicators of future writing abilities. Children establish associations between their gestures and the ideas they wish to convey, a phenomenon also evident in children's drawings. Language acquisition signifies gaining access to the world and the capacity to cultivate intellectual and symbolic proficiencies, thereby empowering individuals to master their intentions and articulate their thoughts.

Concerning the education of deaf individuals, two primary educational approaches emerge: restricted oralism, emphasizing the teaching of oral language through lip-reading akin to hearing individuals, and gesturalism, advocating the early teaching of sign language to facilitate the development of deaf children. According to Lacerda (1998), deaf education traces its roots back to the sixteenth century in Spain. However, before 1750, deaf individuals exhibited limited literacy and minimal opportunities within the job market. The first school for the deaf was founded in France in 1756. In 1880, during the World Congress of the Deaf in Milan, the oralist approach was adopted, effectively banning sign language in deaf schools. Sacks (1998) concluded in "Seeing Voices" that deaf individuals exhibit a natural inclination toward sign language rather than speech, with sign language proficiency requiring dedicated teaching and years of practice.

The crucial aspect to emphasize is that profoundly deaf individuals demonstrate no innate predisposition towards spoken language acquisition. Speaking is a skill that necessitates explicit instruction and years of effort. In contrast, they exhibit an immediate and pronounced inclination toward sign language. Sign language, being a visual language, is inherently accessible to this population (Sacks, 1998).

This text outlines the historical evolution of deaf education, highlighting the period during which oralism predominated, suppressing the use of sign language. It wasn't until 1971 that sign language regained recognition, with 1975 marking the acknowledgment that oralism did not adequately address the educational and societal inclusion needs of deaf individuals. In 1981, research led to the adoption of bilingual pedagogy, advocating the teaching of sign language as a foundational step, followed by instruction in the local written language. In Brazil, the National Institute of Deaf Education (INES, 1988) espouses bilingualism as its educational philosophy. It's worth underscoring that sign language possesses its own linguistic structure, necessitating early instruction for deaf children to facilitate cognitive development.

For a deaf child, the acquisition of two languages is pivotal for integration into society. Despite Brazilian Sign Language (LIBRAS) being recognized as Brazil's second official language, its instruction remains largely confined to specialized schools. This persists despite legal provisions for the inclusion of deaf individuals in mainstream educational institutions. The dearth of educational materials designed to teach both languages poses a challenge to educators, who frequently resort to inventive techniques, such as comics amalgamating LIBRAS and written Portuguese. Moreover, the absence of educational resources tailored to the specific needs of deaf children, particularly those demanding intense visual stimulation, presents another obstacle. It is imperative that deaf children encounter their native language and the associated socio- cultural values, with mothers playing a pivotal role in nurturing a child's initial discoveries of the world and linguistic development. In households where parents are hearing and the child is deaf, the absence of visual stimulation can impede the child's development, relegating them to rudimentary gestural communication. Ideally, hearing parents should acquire proficiency in Brazilian Sign Language (LIBRAS) and actively engage in visually stimulating activities during the child's critical phase of visuospatial language acquisition.

The following steps will be presented for the development of the bilingual story project, which aimed to assist in the language acquisition process for deaf children.

## Steps for the creation of bilingual digital stories

Our research followed a structured process for the creation of bilingual digital stories:

1st Stage: Bibliographic and Documentary Research We began with an extensive review of sources to establish the theoretical foundations of our project. Our goal was to explore the relationship between contemporary digital technologies in education and the user experience. We aimed to contribute to the advancement of knowledge in this field by addressing questions related to designing interactive systems for meaningful experiences. We also sought to understand the real experiences of the agents involved and the dynamic between these agents.

2nd Stage: Definition of Visual Identity Understanding our target audience was paramount. We conducted an analysis that considered their visual preferences, age group, and specific characteristics. Based on this analysis, we developed an attractive and cohesive visual identity for our platform. This included decisions regarding color schemes, typography, icons, and the selection of appropriate images.

3rd Stage: Visual Story Creation This phase involved the development of the story's visual elements. We crafted the storyboard, characters, illustrations, scenes, animations, and the layout of story screens. All of these elements were created using defined media.

4th Stage: Development of Interactive Features Our next step was identifying and planning the interactive features that would be integrated into the platform. These features encompassed animations, videos, text, sound design, and narration. Our design approach ensured that these features promoted active participation by both deaf and hearing children, with a strong focus on accessibility and user-friendliness.

5th Stage: Prototype Development We tackled issues related to presenting information in a non-linear manner, such as utilizing hypertext in a structure of semantically linked nodes. This approach offered multiple alternatives for navigation and interaction. During this phase, we established high-level requirements for the platform and created wireframes and accessibility interaction elements.

6th Stage: Usability Testing and Optimization To ensure a user-centric design and a seamless user experience, we conducted rigorous usability tests with our target audience. These tests identified potential issues and provided valuable feedback. Based on this feedback, we made improvements and optimizations to the platform. Continuous monitoring and analysis of performance were essential to ensure its proper functioning.

Adopting the steps mentioned above and based on the Social Design Principles by Margolin (2004) we created a digital book for deaf and hearing children. The authors emphasize the primary objective of social design as "the satisfaction of human needs, especially those of individuals with low income or specific needs related to age, health, or disability" (2004, p. 44).

This proposal for a social action model in the design field underscores the importance of qualities such as empathy, active listening, and collaboration. It advocates for the involvement of clients, users, and communities in co-creating solutions that truly cater to their unique needs, rather than imposing designs that might not align with their aspirations.

Margolin (2004) suggests that designers must comprehend the dynamics and interactions among all stakeholders involved in a project, as well as the environment in which these interactions occur. This comprehensive understanding defines a system, and the entire design process should be collaborative. These principles have been fundamental in our efforts to create digital stories for deaf and hearing children, which constitute the focus of this study.

## Inclusive visual narratives for deaf and hearing children

The convergence of design, digital humanities, and visual storytelling is pivotal to the development of inclusive educational materials for deaf children. Through the creation of interactive stories that utilize both Brazilian Sign Language (LIBRAS) and written Portuguese, we can provide a more enriching and meaningful learning experience for these young learners. According to Lupton (2020), design elements such as typography, color, layout, and imagery serve as potent tools for conveying messages and narratives in a clear and impactful manner. She also contends that design is, in essence, a form of "storytelling" with a structure akin to traditional narratives—beginning with a problem, navigating through conflict, and culminating in a solution. This perspective underscores that design goes beyond aesthetics; it's about how messages are communicated and how they resonate with the audience.

Hence, Lupton's (2020) notion of design as a form of visual communication that narrates stories and delivers messages clearly and effectively becomes particularly relevant. Design is a powerful instrument for breaking down communication barriers, rendering information more accessible and inclusive. It should aspire to be inclusive and accessible to all, including those who are deaf. Design can transcend language barriers and enhance the understanding of information for individuals who communicate differently.

The amalgamation of design, digital humanities, and the creation of visual narratives stands as a cornerstone in crafting accessible educational materials for deaf children. The development of interactive stories, complete with illustrations and animations that incorporate LIBRAS and written Portuguese, holds the potential to offer a more engaging and impactful learning journey for these children.

Digital technology has paved the way for innovative forms of visual narratives that transcend traditional media like cinema and television. These digital narratives empower viewers to actively engage with the storyline. For instance, in video games, players take on an active role in shaping the narrative, making decisions that influence its course. Digital visual narratives exhibit distinctive features, such as the capacity to manipulate timelines, enabling users to navigate backward and forward within the story. Furthermore, these narratives seamlessly integrate various media elements, including text, images, sound, and video.

Digital visual narratives introduce the concept of immersive virtual worlds, inviting viewers to explore and enhance their narrative experiences. These virtual realms can serve both entertainment and educational purposes, particularly in bilingual education by facilitating the simultaneous presentation of LIBRAS and written Portuguese.

Language acquisition is paramount, as it serves as the foundation for organizing thoughts and active participation in society. In Brazil, a significant challenge in bilingual literacy education for deaf individuals is the simultaneous teaching of LIBRAS and written Portuguese. By leveraging visual and interactive resources, we can capture children's attention, enhance comprehension, and facilitate the assimilation of content. Additionally, digital technologies offer the potential to broaden access and distribution of these materials, reaching a wider audience and expanding their societal impact.

Through the application of inclusive and user-centered design methodologies, as well as interdisciplinary collaboration, we can develop educational materials tailored to the unique needs of deaf children. These materials play a crucial role in fostering their integration and inclusion in society.

The journey to support language acquisition for deaf children commenced with the project titled "Design and Contemporary Digital Technologies Applied to the Development of Interactive Digital Books for Deaf and Hearing Children," which received recognition from the National Council for Scientific and Technological Development. This initiative aims to create digital books for deaf children, presented in illustrated and animated formats, with a special emphasis on LIBRAS, considering its predominantly visual-spatial nature. As we evaluate the results of this project, it becomes evident that there is a pressing need to develop, systematize, and implement a digital platform for managing, collecting, and distributing these stories. The creation of stories designed for this project will soon be accessible through an inclusive digital platform.


***Figure1: Prototype of the first story called Ana e José. Source: authors archive.***

***https://www.youtube.com/watch?v=1fTZtjmtt9g,***

## Testing Bilingual Digital Books: Enhancing the Project for Deaf and Hearing Children]

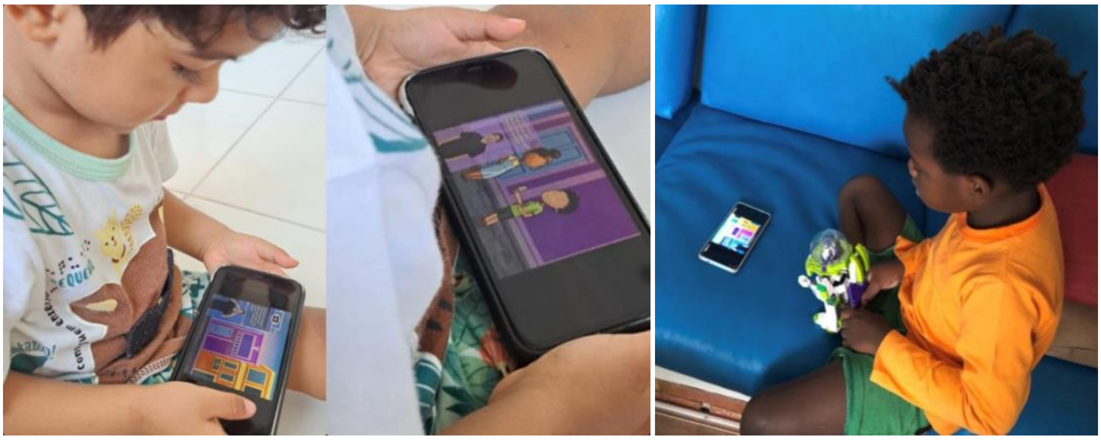


***Figure 2: Deaf and hearing children reading the book Ana e José a story of friendship. Source: authors archive.***

To enhance our project's efficacy, we conducted tests involving two groups of children: one comprising five deaf children and another of five hearing children, all aged between 5 and 7 years old. Observing how these children interacted with the bilingual digital book was a crucial step in gaining insights to inform future improvements.

During the tests, we provided the children with access to the digital book and closely observed their reactions and behaviours. Here are some valuable insights we extracted:

- Engagement and Interest: We assessed the level of engagement and interest shown by the children in the book's content. This involved measuring the time they spent reading, identifying enthusiasm while exploring the pages, and noting if they asked questions about the story.
- Ease of Use: We evaluated how easily the children could navigate the digital book. This encompassed their ability to flip through pages, interact with elements, and utilize features like audio and animations.
- Comprehension of Content: We verified the children's comprehension of the story and its key concepts. This included asking questions to ensure they grasped the narrative's core points.
- Design Feedback: We collected feedback from the children regarding the overall design of the digital book. This encompassed visual aesthetics, the quality of illustrations and animations, and any confusing or challenging aspects encountered.
- Interaction with Bilingual Resources: We observed how both deaf and hearing children interacted with the bilingual resources, including the transition between LIBRAS and Portuguese. Our aim was to understand how these resources contributed to their understanding of the story.

Based on the observations and feedback gathered during the tests, we are better equipped to make improvements to the project. This may involve adjustments to the user interface, narrative structure, the presentation of bilingual resources, or any other areas that can enhance the children's experience with the bilingual digital book.

These tests with children aged 5 to 7 years play a pivotal role in the development process, ensuring that the project aligns with the needs and expectations of the target audience. This approach facilitates an engaging and effective learning experience, underscoring the importance of a user-centred approach in designing educational resources for both deaf and hearing children.

Through our research, we identified that bilingual stories in LIBRAS and Portuguese have yielded significant benefits, including language development, visual stimuli, contextualized learning, and enhanced accessibility.

Building upon this work, we have developed an instrument that allows deaf children to engage in interactive stories via a tablet or smartphone application. These narratives are presented using diverse media: sounds, images, texts, and videos. This enables deaf children to associate LIBRAS with images and text while sharing the experience with their hearing peers, who can enjoy the auditory aspects, such as music and narration.

Bilingual digital stories play a pivotal role in supporting language development for deaf children in both LIBRAS and Portuguese. They provide a visual and gestural representation of words and phrases, simplifying language comprehension and acquisition. Visual elements, including images and animations, captivate the attention of deaf children and aid in content understanding—highlighting the role of visual communication in Deaf culture.

Moreover, these stories depict everyday scenarios where language is used, helping deaf children grasp word and phrase applications in various contexts. This adaptability ensures personalized and accessible learning, making these stories an excellent complement to formal LIBRAS and Portuguese education.

In conclusion, bilingual digital stories can significantly contribute to the acquisition of LIBRAS and Portuguese by deaf children. Their visual and contextualized approach to language learning offers numerous benefits, as evidenced by our research. Our studies have highlighted key guidelines for integrating LIBRAS and Portuguese:

- Narrative Bilingualism: Include both Brazilian Sign Language (LIBRAS) and Portuguese to foster proficiency in both languages.
- Visual and Textual Integration: Combine visual and textual elements, such as illustrations, animations, and subtitles in Portuguese and LIBRAS, to enhance understanding and reinforce learning.
- Accessibility Focus: Develop narratives with accessibility in mind, ensuring they cater to the needs of deaf children who use hearing aids or support technologies.
- Culturally Relevant Content: Include themes and stories that resonate with the cultural experiences of deaf children, promoting identity and self-esteem.
- Interactivity: Incorporate interactive elements to sustain the interest and engagement of deaf children, such as educational games and interactive activities tailored to the target audience's preferences.

Inclusive design plays a pivotal role in ensuring that educational materials cater to the needs of all users, including those with disabilities. For children, especially those with hearing impairments, inclusive design can significantly enhance the accessibility and usability of educational materials, making the learning process more effective and enjoyable. As such, it is crucial to critically reflect on the role of design in crafting accessible and inclusive visual narratives for deaf children, with the goal of promoting equal opportunities and fostering the full development of their language.

Sacks (1998) emphasizes the vital importance of integrating deaf children into society by providing them access to sign language, a natural, visual, and spatial language. This inclusion empowers them to participate in deaf communities, communicate freely, and cultivate a positive cultural identity, rather than being compelled to conform to dominant cultural standards or facing isolation and exclusion. For Sacks, sign language isn't just a means of communication; it's a rich form of expression and thought that allows deaf children to convey their ideas and emotions comprehensively.

Visual narratives play a pivotal role in the language development of deaf children as they facilitate the construction of a visual repertoire and the comprehension of abstract concepts in a more concrete manner. As Quadros (1997) notes, images, just like writing, are a language and therefore can be used as a tool to enhance communication between the deaf and society in general. Additionally, the use of images fosters the attribution of meanings and enriches the understanding of the world, enabling deaf children to enjoy a more diverse and enriched experience.

Based on the studies conducted during this research on the creation of bilingual stories to develop effective visual narratives, Portugal (2022) emphasizes the following considerations:

- Integration: Visual narratives should seamlessly incorporate various visual elements like images, graphics, animations, and text to create a cohesive and harmonious visual experience.
- Sequencing: Visual narratives should follow a logical sequence of events, ensuring that the story is comprehensible to viewers. The narrative rhythm should also be considered to maintain viewer interest and attention.
- Hypertextuality: Visual narratives should offer viewers access to additional information about the story through hyperlinks or other connections, enhancing the overall narrative experience.
- Multimodality: Visual narratives should incorporate a variety of multimodal elements, including sound, music, and sound effects, to create a more immersive sensory experience.
- Participation: Visual narratives should empower viewers to actively engage with the story, allowing them to interact with the narrative in various ways, such as making choices, voting, or contributing to the story's development.

In light of these considerations, it becomes essential to explore novel approaches to design, as highlighted by Manzini (2004) in the context of a "fluid world." In such a world, where products, services, and information converge to generate unprecedented design possibilities, designers must adapt their professional profile to become facilitators within a network. Their role shifts to that of providers of the innovation process rather than direct executors.

Manzini (2004) underscores that designers, with their creativity and communication skills, can play a crucial role in promoting high levels of social participation. These ideas align seamlessly with the concept of designing for digital humanities projects, where designers act as enablers and collaborators within complex networks, driving innovation and social impact.

## Conclusion

The intersection of design and humanities is crucial for creating projects that respond to social, cultural, and technological needs. A collaboration between the two fields can result in innovative solutions that reflect the complexities of society and human experiences. A humanistic approach in design values empathy, ethics, and social responsibility, promoting inclusion and diversity in the projects created. This interaction can lead to projects that cater to the unique needs and expectations of users while considering their cultural values and meanings. Collaboration between designers and digital humanists has become increasingly important to create effective projects that enable people to interact with technology through design interfaces. Design practices encompass a set of research and experiences that make digital resources more intuitive and accessible in the social sphere.
The relevance of the interrelation between design and digital humanities in the creation of visual narratives becomes relevant because digital humanities seek not only to explore technological potential, but also to question and problematize its uses and effects on society.

Technologies have been blamed for various social, economic, and ecological problems. However, new technologies create forms of social action and organization when accepted by the culture in which they are inserted. Design, classified as material and immaterial culture of societies, interferes in our environment and, therefore, it is necessary to reflect, study, and understand this field of action and research.

Currently, there has been a growing interest in the area of deafness, especially among linguist researchers, educators, psychologists, among others, since this theme constitutes a fertile field for discussions. Research brings the designer to this universe of investigation, and their participation is given through instruments specific to their field of expertise. The stories do not aim exclusively to provide narratives to assist in language acquisition by deaf children. The project has a broader purpose. In it, images and illustrations are used to awaken curiosity and the senses, attributing meaning and stimulating the understanding of the world, of the universe of each story. The texts, presented with illustrations and images, are capable of enchanting children with colours and shapes, stimulating imagination and creativity, and arousing interest in juvenile literature.

Based on the research conducted, it was possible to identify those bilingual stories in Libras and Portuguese for deaf children generated some benefits, such as language development, visual stimuli, contextualized learning, accessibility in support of learning.

Bilingual digital stories can help deaf children develop their language skills, both in Libras and in Portuguese, because these stories provide a visual and gestural representation of words and phrases, which facilitates language comprehension and acquisition.

By often including visual elements such as images and animations, these materials can capture the attention of deaf children and improve their understanding of the content. This is especially important because visual communication plays a key role in Deaf culture.

Bilingual digital stories can also present everyday situations in which language is used, helping deaf children understand how words and phrases are applied in different contexts, as well as allowing adaptations to meet the individual needs of deaf children, such as speed presentation of content or repetition of information. This makes learning more accessible and personalized.

Digital stories can be used as a complementary tool to formal teaching of Libras and Portuguese, providing deaf children with the opportunity to practice their language skills in a fun and engaging way. We believe these benefits underscore that bilingual digital stories can play an important role in promoting the acquisition of Libras and Portuguese by deaf children, providing a visual and contextualized approach to language learning.

In conclusion, design can contribute to the construction of a clearer and more accessible narrative, allowing data to be understood more efficiently and intuitively by users. In addition, design can help in the organization and structuring of data, making them more readable and facilitating the identification of patterns and trends. It is important to emphasize the importance of collaboration between designers and digital humanities experts to create effective and meaningful solutions. The humanistic approach in design values empathy, ethics, and social responsibility and can promote the inclusion of deaf children in society.

## Acknowledgements

This work was supported by the National Council for Scientific and Technological Development - CNPq, with the Research Productivity Grant PQ/CNPq, process no. 308786/2018-1

## References

Burdick, A., et al. (2012). Digital Humanities. Massachusetts: MIT Press.

Burdick, A.; Drucker, J.; Lunenfeld, P.; Presner, G. (2020). A Brief Guide to Digital Humanities. Teccogs Journal, 21, Jan-Jun 2020.

Drucker, J. (2014). Graphesis: Visual Forms of Knowledge Production. University Press.

INES (1988). Proceedings of the II Meeting on Literacy for Hearing Impaired. Rio de Janeiro: CIMART.

Lacerda, C. B. F. (1998). A Glimpse of the History of Different Approaches in Deaf Education. Cad. CEDES, 19(46), Sep 1998. Available at: https://doi.org/10.1590/S0101-32621998000300007. Accessed on: April 25, 2023.

Lupton, E. (2020). Design como storytelling. Barcelona: Editora Gustavo Gili.

Manzini, E. (2004). Design as a Tool for Environmental and Social Sustainability. In: Macdonald, S. (ed.) Design Issues in Europe Today. Barcelona: BEDA.

Margolin, V.; Margolin, S. Um Modelo Social de Design: questões de prática e pesquisa. Revista Design em Foco, Salvador: EDUNEB, v.1, n. 1, jul./dez., p. 43-48.

Quadros, R. M. (1997). Education of the Deaf, Language Acquisition. Porto Alegre: Artmed.

Portugal, C. (2022). Design * Technology. 2022. Available at: www.dxtdigital.com.br. Accessed on: April 25, 2023.

Portugal, C. (2019). Design in the Complex Context of Media. Rio de Janeiro. Estudos em Design (online), v. 27, No 2, p. 77 – 91.

Portugal, C. (2018). Grumari: Storytelling. In: EVA LONDON 2018 Electronic Visualization and the Arts. London: BCS Learning & Development, p. 2013 – 220.
Portugal, C. (2017). Design and Visual Arts for Digital Literature. In: EVA LONDON 2017 Electronic Visualization and the Arts. London: BCS Learning & Development, p. 235 – 241.
Sacks, O. (1998). Seeing Voices: A Journey into the World of the Deaf (Translation by Laura Teixeira Motta). São Paulo: Companhia das Letras.
Sayers, J. (2018). Making Things and Drawing Boundaries: Experiments in the Digital Humanities. University of Minnesota Press.
Vygotsky, L. S. (1987). Thought and Language. Cambridge, MA: MIT Press.

# Exploring Girls' Narratives in Competition-Based Educational Robotics

**Thomas Kennedy, Memorial University of Newfoundland, Canada**

## Abstract
The purpose of this study was to explore the perceived sense of comfort and belonging of girl participants, aged 15-16, engaged within a school-based offering of the Marine Education Advanced Education (MATE) underwater remotely operated vehicle (ROV) program (MATE-ROV). MATE-ROV is a competition-based educational robotics (ER) program that can offer experiences in the design, fabrication, and testing of an original ROV similar to what one would experience in relevant sectors of the marine industry. A qualitative case study design was selected to document and analyze participant narratives and explore their sense of belonging within the intragroup and intergroup contexts. With a purposeful sample of 5 (N=5), the study gathered data using a three-phased approach with data collected through the use of questionnaires, interviews and observations. The study sought to answer the overarching research question: How do experiences in educational robotics impact feelings of comfort and belonging for girl participants? Three primary findings emerged from this qualitative study. First, intragroup relationships foster a connected social identity that can support comfort and belonging. Second, a connected social identity does not automatically build a perceived expansiveness in comparable groups. Third, successful domain performance or effectiveness does not compensate for the potential impact of stereotype threat.

## Keywords
Case Study, Social Identity Development, Educational Robotics, MATE-ROV, STEM Capital

## Introduction
The Marine Education Advanced Education (MATE) underwater remotely operated vehicle (ROV) competition, or simply MATE-ROV, is an international program designed to engage participants in technological activity grounded in marine-based disciplines. School-based, educational robotics groups work over an extended period to design and prototype an original ROV-based solution to perform underwater tasks or missions. Each year, new parameters are published in a scope document that outline the limitations where each innovative solution can be quite different. The MATE-ROV program offers a unique opportunity where participants are able to work collaboratively within their local setting but also compete at a regional competition against other schools, a comparable structure to varsity athletic programs. Participants can therefore develop technological capacity and gauge their place within the larger population at competition.

Calipso Robotics is one such school-based MATE-ROV program at a small K12 school (student population 155) in eastern Canada. Over the course of three years, an anomaly occurred within the local group whereby the team became all-girl despite being open to boys as well. The phenomenon became more irregular as the group competed at provincial competition as the first all-girl team and even earned top score in the product demonstration in their third year of competition. The following qualitative case study captures their unique narrative as they reflect on their sense of comfort and belonging in robotics and their experiences within the local school-based program (intragroup) versus their experiences at competition amid the larger population (intergroup).

## Literature review

Educational Robotics (ER) is a means to offer early experiences in science, technology, engineering, and mathematics (STEM) (Cano, 2022) where participants actively engage in some aspect of designing, prototyping, programming, and controlling a robot. Zuhrie et al. (2021) published a literature review to highlight emergent themes across the field of study. Their review supported two foundational elements common to the majority of ER programs. First, they are based on a project-based learning approach but programs can range from the assembly of a kit to the innovative prototyping of an original system. Second, they foster some degree of STEM-based skill development that can range from programming to construction to electronics. ER programs have gained a foothold in many schools as large-scale competitions gain popularity on an international level (Cano, 2022; Sullivan & Bers, 2019; Zuhrie et al., 2021). Competition-based ER was noted to develop “practical skills through the direct practice of … operating robots” (Zuhrie et al., 2021, p. 6). Brancalião et al. (2022) processed 673 papers that covered 50 competitions in their comprehensive literature review. Their work found that robotics competitions commonly featured aspects of industry. Participants build a robot to perform some activity based in real-world problems, work in teams, and develop hard and soft skills.

Research can be found that explore comparable contexts to this study, experiences of similarly aged participants engaged in ER programs that feature competition. One of the largest ER competitions is the Vex Robotics Competition (VRC) (Brancalião et al., 2022). Stewardson et al. (2018) published a study to look at participation in VRC which boasts over 18 000 teams worldwide. Their work connected the concept of self-efficacy as an indicator to predict success. The study found that the number of seasons of participation had a positive impact on perceived self-efficacy, a construct that is essential for choosing pathways that lead to further STEM-based activity and even careers. Another study based within the realm of VRC sought to examine the experiences of male and female participants to gain insight regarding the causes of attrition amongst girls across school-based programs. Sullivan and Bers (2019) conducted their study based on the experiences of program mentors and participants engaged in VRC across the United States. Their findings confirmed the lack of girls at the mentor and participant levels. It was also noted that girl participants had greater concern regarding the social repercussions associated with participation in ER, an area where they lacked confidence. They expressed fear of embarrassment and estrangement. They also communicated a perceived sense that the boys were entering with more experience, especially as it relates to aspects of fabrication.

### A Sociological Perspective

As participants collaborate, they form a group of individuals that are interdependent for the attainment of a common goal. Literature to explore the sociological perspective of group dynamics pre-dates any implementation of ER programming. Turner (1982) noted that interdependence leads to cooperative social interaction and cohesion where members become bound to each other, the group as a whole, and the activity at hand. Intragroup relations can be characterized by (1) a perceived similarity of members, (2) social cohesion, (3) positive self-esteem, (4) emotional empathy, (5) cooperation, and (6) uniform attitude / behaviour (Turner, 1982, p.29). Intragroup relationships denote the dynamics within a single group. It involves the behaviours, attitudes and general group cohesion of a single unit. The cohesion that forms during group activity can support feelings of comfort and connectedness. Wenger (2000) described the intragroup connectedness as “a lived sense of belonging (or not belonging)” (p. 239), a construct that is strengthened through shared histories and experiences. But, his work noted that connectedness is just one of three qualities that support a balanced social identity. The expansive and effective pillars support the building of positive self-concept within the larger community. An expansive identity is one that would be accepted within comparable groups that value similar competencies. An effective identity supports engagement with performance within this intergroup context.

Wenger’s (2000) work suggested that a balanced social identity is a construct that is grounded and strengthened in local experience but universal enough to foster a sense of belonging within the greater domain. Individuals move away from their immediate peer group to interact with others that may share similar values. Intergroup experiences describe the behaviours, attitudes, perceptions, and interactions between two or more distinct groups. These experiences can be limited in non-competition-based programs as groups are not given the opportunity to interact with their counterparts from other schools or regions. This limitation can often negatively impact intergroup perceptions. Brown and Ross’ (1982) earlier work commented on this limitation, noting that feelings of bias and antipathy between groups are proportional to perceived threat to their social standing. ER programs such as MATE-ROV afford participants unique intergroup experiences where they are able to situate themselves within the larger field of robotics and evaluate their self-concept and sense of belonging.

**STEM Capital**

Archer et al. (2015) sought to understand how the various types of capital support engagement and participation in science. Their work focused on the scientific forms of cultural and social capital, or *science capital*, and its uneven distribution within society. The study calculated a science capital score based on survey data from 3658 participants, aged 11-15 years, basing their analysis on indicators regarding scientific forms of cultural capital; science-related behaviours and practices; and science-related forms of social capital (p.929). Participants were placed into three groups according to their exhibited level of science capital: low, medium, and high. Low science capital was defined as those students with limited scientific literacy, less engagement with extra-curricular science activities, and social networks with limited science-related jobs. High science capital was defined as those students with developed scientific literacy and access to science-related cultural and social resources (p. 936). Higher levels of science capital were found to be more concentrated among boys. Archer et al. (2015) found a direct correlation between science capital and science identity whereby participants with high science capital were secure in their perceived belonging in the field and felt the identity was validated by others. Those participants with low science capital felt that others did not view them as a science person (p.938). Similarly, students with higher science capital were more confident in their science abilities. The authors noted a trend for medium science capital student, 67% of their participants, to be representative of a larger sample and remained unsure of their science identity despite having medium level of confidence in their abilities. Low science capital students, 27% of their participants, were identified as primarily female and while they may find science interesting, they do not consider themselves to be that type of person.

Later research conducted by Archer et al. (2020) continued to explore the factors shaping aspirations and identities building on his conceptualization of *science* capital and even acknowledging a broader notion of *STEM* capital (p.8). The second phase of their large-scale study in England, ASPIRES 2, found that high levels of science capital were likely to translate to positive attitudes towards the four subcategories of STEM. As the findings of ASPIRES 2 underscored the impact on the larger field of STEM, it brings the relevance closer to the current study. The longitudinal research supported the trend that boys, in particular, having family members with science qualifications and / or jobs were more likely to aspire to a career in science. Additionally, Archer and colleagues wrote of the trend for engagement to be shaped by the participant's science-related self-concept. Science self-concept was determined to decrease as students progressed through secondary school, aligning with the age of the participants in this study. The survey data showed that while STEM clubs were associated with higher trends of positive attitudes, the responses from some girls described their discomfort in attending such programming when they were dominated by boys. But, when science is largely considered a masculine pursuit, it is not surprising that the science self-concept of girls was reported to be significantly lower than the boys.

**Gendered Programming**

Exposure to technology activity could work to establish an early sense of belonging in technical work. Sultan et al. (2023) conducted a study of a three-day technology camp for Swedish teenage girls where activities were re-designed to be girlified – "the act of making otherwise not gendered artefacts girly…transformed from a male or neutral to a more feminine coded object (Discussion, para. 2). The authors found that participants who had already established a self-concept of being technical did not find the efforts to girlify the activity appealing. Their findings also highlighted the social connection that exists between participants whereby participants feel a sense of belonging and technical capacity because of a supportive social context.

Girls are rarely the dominant demographic in STEM-based programs without gender-based interventions. Kim et al. (2018) published an empirical research focused on the STEM-based experiences of girls which highlighted the importance of supportive relationships. Interpersonal connections work to foster the development of self-esteem and counter the trend for girls to inaccurately rate their own competencies. They proposed that programs must create and maintain a balanced perspective of what constitutes the ingroup or prototypical identity to combat the attrition of girl participants. Cano (2022) conducted a recent mixed-methods study to design a methodological approach for teaching STEM-skills through ER with a gender focus. Their study highlighted the trend for females to develop a sense of estrangement in STEM-based contexts and to be more passive when tasked with the fabrication of robots. The findings underscored the potential for gender-focused ER-based workshops to foster interest and curiosity in girls where they noted an increase in participation. Hernandez et al. (2017) reported results of a theory-driven mentoring program to support female students enrolled in post-secondary STEM majors. The findings of their study were based on their mentorship of eighty-five participants and suggested that to develop professional identity, learners must see themselves as professionals, become a part of the community and be recognized by their mentors. They found that girls can experience social barriers that "undermine their scientific development, motivation, and persistence in STEM education and career pathways" (p. 10). Girls who received explicit mentorship reported higher levels of scientific identity and interest.

Yet, literature also proposes that efforts to create gender-focused programming can perpetuate stereotypes and appear condescending. Watermeyer's (2012) three-year ethnographic and longitudinal study found that same-sex programs in STEM "served not to reverse but reproduce and accentuate the manifestation of gender inequality" (p. 696). Gender-focused programming seek to stimulate scientific interest amongst girls but risk imposing gendered identity and perpetuating the ingroup. At the institutional level, Allen and Eisenhart (2017) proposed that the historical narrative has contributed to poor identity development for girls in STEM-related disciplines. Their ethnographic and longitudinal study focused on four young women as they "negotiated STEM-related identities in the discursive and practice contexts of their lives at school" (p. 407). Findings from their study highlighted the need to address the intersection of gender and STEM more explicitly at the institutional level to allow opportunity to those groups that remain underrepresented. Their work noted a similar concern that addressing girl STEM identity development with gender-based solutions may be misleading and assumptive. Later work by Goreth and Vollmer (2022) echoed a similar position that the existing gender gap in technological domains cannot be reduced to gender-focused programming. Their findings highlighted that the interest in STEM is strengthened through technical socialization and compulsory technology education courses, regardless of gender identity. The authors noted that the implementation of technology education curriculum for all could help sensitize supporters to the topic to help establish the self-concept of girls in STEM (p.1693).

Sparks (2017) warned that assumptions made of individuals based on their demographic do not account for their lived experiences. His work explored the potential for gender-based solutions to impede girls in STEM in two ways. First, it may steer them away from gender specific programming where they do not feel comfortable. He noted that interventions cannot be reduced to a pipeline perspective that "erroneously suggests that the more girls who are stuffed into one end, the more that will turn out of the other end of the pipe to complete their degree and chose STEM as a lifelong career" (p.12). Second, individuals may respond by adapting to the gendered spaces by temporarily suspending aspects of their identity to conform to their environment and ensure acceptance. For example, a girl engineering student may feel they must enjoy video games and be 'geekish' to fit the prototypical identity or risk social repercussions. Earlier literature on stereotype threat offers a similar perspective, where stereotype threat is the "socio-psychological ... situational threat ... that can affect members of any group about whom a negative stereotype exists" (Steele, 1997, p. 614) where an individual "is concerned about being judged or treated negatively on the basis of this stereotype" (Spencer et al., 2016, p. 416). Pressure to outperform and disprove stereotype threat, especially by the vanguard, can be daunting. Spencer et al. (2016) named three aspects of stereotype threat that can lead to underperformance. First, underperformance may result from extra pressure to succeed. Second, underperformance may result from threats to self-integrity and belonging where participants may self-handicap to protect themselves. Third, underperformance may result from priming the stereotype. Beyond the potential for underperformance, Spencer et al. (2016) also noted the potential for stereotype threat to influence an individual's sense of belonging and their motivation to engage and commit to any given domain.

The literature review was a scoped exploration of potentially meaningful themes associated with the context of this study. It sought to examine existing themes within the field of study in relation to (1) educational robotics, (2) social identity, (3) STEM capital, and (4) gendered programming. The review has offered a preliminary lens to examine the lived experiences presented by the study participants.

## Research Question

The purpose of this study was to capture, analyse, and discuss the narratives of a group of girls engaged in educational robotics at the intragroup and intergroup contexts. Their narratives can speak to the unobservable, their perceived sense of comfort and self-concept. Sparks (2017) noted that the first step to addressing the attrition of girls in STEM-related activity is to conduct more qualitative studies to explore the development of identity within these contexts.

This study was conducted to explore a sociological perspective as participants reflect on their intra- and inter-group belonging. The findings of this study offer insight that is applicable to comparable programming across jurisdictional boundaries (i.e.. Ministries of Education, School Districts, School Boards, Schools). The main research question that guided this study was: How do experiences in educational robotics impact feelings of comfort and belonging for girl participants?

## Methodology

A qualitative case study design was selected to analyse emergent themes from an in-depth exploration of participant experiences within an educational robotics program. Flyvberg (2011) noted the potential for case study to emphasize an intentional object of study, a phenomenon that justifies further exploration. The ER program at the centre of this study exhibited an all-girl ingroup which did not align with the trend for robotics to be a typically masculine activity. The case fulfilled the three conditions outlined by Yin (2014) whereby (1) the study's research question seeks to understand a singularity, (2) the study does not separate the phenomenon from its context, and (3) the study focuses on a contemporary case rather than an historical one. An understanding of this phenomenon may offer insight for similar programs that seek to address the underrepresentation and attrition of girls.

### Participants

The participants of this study formed a purposeful sample where eligibility was based on candidate membership in the educational robotics program, Calipso Robotics, from 2016-2019. There were 5 candidates eligible for the study with all 5 (N=5) agreeing to participate. Miles et al. (2014) noted that it is common for qualitative studies to work with such small groups especially as it highlights a phenomenon. All participants were in grade 10 (age 15/16) at the time of the study and reflected on their experiences from grades 7-9 (ages 12-14). The participants were assigned pseudonyms - Chloe, Olivia, Isabella, Jessica, Emily - in order to reference specific experiences across the data analysis narrative.

### Data Collection

A multiphase design for the data collection process was adopted for this case study where the focus was to gather thick, richly descriptive data to document the lived experiences of each participant. All instruments used to collect data were original and drafted to include protocols.

Phase I began with a questionnaire. The protocol featured prompts such as: "How did you get started in robotics?", "Please describe your experiences within the extra-curricular robotics program.", and "Please describe your comfort level participating in technical activities like robotics and competing at the provincial level.”. The questionnaire was distributed to participants digitally and designed to aid in the initialization of participant profiles and gather preliminary perspectives.

Next, phase II continued with an interview that was designed to be semi-structured and flexible. The protocol was drafted to probe for deeper understanding. The interview was conducted in a face-to-face, one-on-one capacity where each participant was able to offer their narrative independently of the group. The protocol included questions and prompts such as: “In what ways did collaboration with peers influence your experiences?”, “What factors have influenced you to come back [to educational robotics] each year?”, and “In what way, if any, do you adopt a different identity when engaged in [educational robotics]?”. Phase II also included observations of the participants as they engaged in their program. Observation is a method commonly used in case studies (Merriam & Tisdell, 2016) which can be used to discover the complex interactions within the context of the study (Bloomberg & Volpe, 2016).

Phase III marked the final step in the data collection process where participants were given the opportunity to review their data. Each participant completed this phase with no edits to be made to the data. This step was an important piece to ensuring the data captured an accurate representation of their lived experience and voice.

**Data Analysis**

Miles et al. (2014) stressed “the apparent simplicity of qualitative data masks a good deal of complexity” (p.11). As expected, the data collection process of this study produced a large amount of raw data. An analysis plan was created to remain consistent in handling the voluminous amount of participant narrative. The plan was based upon the work of Braun and Clarke (2006) that suggested steps for thematic analysis to ensure a systematic approach.

***Table 1. A thematic analysis plan based on the work of Braun and Clarke (2006).***

| Step | Description |
|---|---|
| Step I: Familiarization | • Exporting the questionnaire data from the online form.<br>• Transcribing the interview data.<br>• Reading and re-reading the data, noting initial ideas. |
| Step II: Generating Codes | • Importing data documents into Nvivo software.<br>• Searching for segments that captured an idea or topic<br>• Assigning nodes in a systematic fashion across the data |
| Step III: Searching for Themes | • Collating nodes into candidate themes<br>• Gathering all data relevant to each candidate theme. |
| Step IV: Reviewing Themes | • Exporting candidate theme document for review<br>• Checking the candidate themes against the coded data<br>• Generating thematic maps of interconnected node data |
| Step V: Defining and Naming Themes | • Analyzing to refine the specifics of each theme<br>• Reflecting on the overall story the analysis tells<br>• Generating names for each theme. |
| Step VI: Producing the Report | • Writing the final analysis<br>• Exporting appropriate maps and figures<br>• Selecting meaningful and purposeful extracts<br>• Producing a scholarly report of the analysis |

In Step I, the data analysis began with a focus on familiarizing myself with the data. Braun and Clarke (2006) underscored the importance of immersing yourself within the data to ensure familiarity with its “breadth and depth” (p. 87). I began by preparing questionnaire data and printing a physical copy for a pen-and-paper analysis of initial ideas. I searched for segments and the use of keywords, making notes along the margins of the document. The notes made from the questionnaire data was reviewed before moving forward with the interview stage to ensure my protocol was relevant and suited to their experiences. After conducting the interviews, I transcribed all digital recordings myself, a process which was highlighted as an important step to familiarization (Braun & Clarke, 2006). The transcription documents were printed and analysed in a similar fashion to the questionnaire data. All audio recordings of the Phase I interview were also reviewed closely for any errors. Preliminary notes taken throughout this step were used as references to begin the coding process.

Step II of the data analysis process began with the generation of initial codes from the data. Braun and Clarke (2006) noted the importance of giving full and equal attention to each data item while coding. Once the questionnaire and transcription documents were imported into my qualitative analysis software, Nvivo, I coded the data manually, ensuring that all data across the entire set was coded and collated. The software referred to the codes as nodes, objects created and pinned to emerging ideas or themes from within the raw data. Nodes were applied to segments of data that captured an idea or topic which ranged from a few words to larger segments of text. Ryan and Bernard (2003) suggested processing techniques for working through qualitative data. I conducted a digitized version of their *cutting and sorting* technique where I leveraged the tools embedded in Nvivo to identify quotes and expressions within the data. Once coded, I could query the database to determine emerging trends across the entire data (see Figure 2).

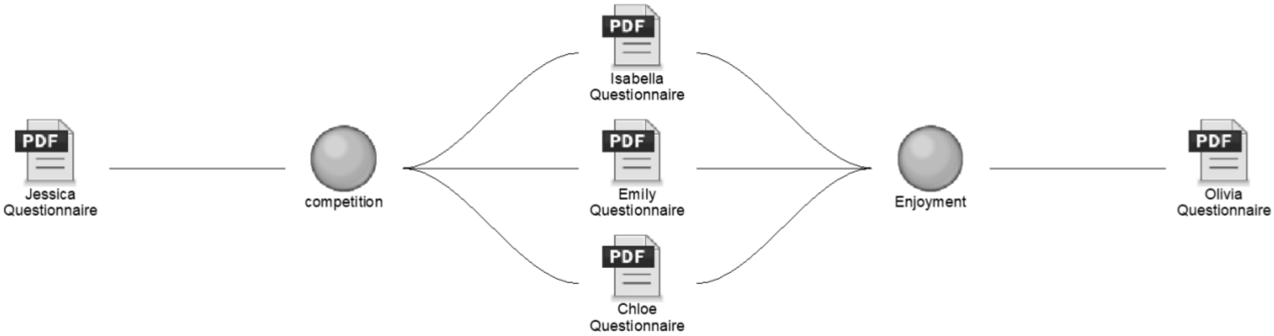



***Figure 2. An example of software-based node comparisons of manual coding in Nvivo.***

I also used Nvivo to create lists of keywords which Ryan and Bernard (2003) highlighted as an important technique to indicate what people are saying. This method generated nodes by exploring the exact words used by participants. Word-based techniques are a fast way to begin searching for trends in data at the beginning stages of research. It was important to code the raw data with as many different nodes as may apply during this step, often as simple as assigning a node to key words and longer data segments. The following nodes are a sample to represent my emergent coding of interesting features of the data:

- Skills Development
- Design Process
- Teamwork
- Friendship
- Enjoyment
- Competition
- Success

At Step III, nodes were clustered to form candidate themes. The nodes can have footings in various candidate themes as overlap across and within the narratives exists. For example, a participant could describe their enjoyment as it may relate to collaboration with peers, engaging in technological activity, and / or experiences at competition. Examples of some thematic categories included, but were not limited to:

- Enjoyment + Friendship + Belonging + Comfort → Peer Relationships
- Stereotyping + Competition + Peer Group + Discomfort → Estrangement
- Activity + Environment + Skills + Confidence → Belonging

Step IV of the data analysis process reviewed the candidate themes that emerged from the coded data during the previous phase. It was here that my process transitioned from manipulative techniques to observational techniques. Ryan and Bernard (2003) suggested that repetition was one of the easiest ways to identify themes where the more the same concept occurs in a text, the more likely it is a theme. Repetition was the primary observational technique adopted to legitimize candidate themes and was facilitated using the Nvivo software. Candidate themes that did not have sufficient support within the coded data were dismissed or integrated into other themes. Braun and Clarke (2006) described two levels to the review and refining of themes. The first level involves the review of the coded data to ensure that the generated themes are fitting. If the themes are coherent, the process moves along to the second level where the themes are reworked to become more appropriate. At the second level, themes are reanalyzed to ensure they accurately represent the coded extracts from the study. Themes were reviewed based on their accurate representation of the overall data set.

The final step of the data analysis plan, Step V, sought to define and refine the meaning of each theme and what aspect of the data set each one represented. Braun and Clarke (2006) explained that this phase should clearly identify the interest of each theme and highlight its importance through detailed written analysis. The refinement of the themes will ensure that the study's analysis is concise and interconnected. Participant narratives repeatedly focused on (1) the importance of intragroup connections, (2) the perceived deficit in expansiveness, (3) the importance of intergroup activity, and (4) the impact of the prototypical identity on perceived belonging. The following section is an overview of these central themes that represent the lived experiences of the participants engaged in this qualitative case study.

## Analysis

### The Importance of Intragroup Connections

All participants identified the presence of their peer group to be the primary reason for initial engagement in ER. They had been friends before engaging in the program and entered as a group. Beyond year one, participants attributed their re-engagement to be contingent on the continued participation of their friends. Participants decided if they were attending from week to week by first determining who would be present and who had other commitments. If too many participants were unavailable, the consensus generally leaned towards waiting for the entire community to be available. Moving forward with their activity was contingent on the presence of a near-full group of their peers.

When asked explicitly if she would have signed up without her friends, Isabella indicated that she was unsure:

> *I didn't really know much about robots, and like, that wasn't really what I was interested in until I started actually going to robotics and learned more about it. And that's what engaged my interest. So, if they hadn't joined in the first place, I probably wouldn't have either.*

The notion of comfort emerged as an important factor pinned to the presence of pre-program friends. It was highlighted that comfort was critical in taking risks and making mistakes within the technical work of the program. Emily highlighted that her comfort level was directly related to her engagement in technical activity amongst friends:

> *At first I was a little nervous about joining the team because I didn't understand the concepts, but after a while I started to get the hang of it and began to enjoy it a lot more ... my teammates helped me a lot with the learning process and it was very comforting.*

Chloe offered a similar emphasis on the comfort she experienced because of the co-participation of her peers and the freedom to make mistakes. She noted, “I’m not embarrassed if I get something wrong because I’m comfortable with my friends so it’s like I’m safe to have an opinion”.

Isabella expressed that the reengagement of her teammates year-after-year was a motivational trigger for her own continued participation. Jessica and Chloe shared a similar perspective, in that their initial engagement was triggered by a shared interest amongst most of their friends and, like Isabella, were doubtful on their continued participation without their presence. When asked explicitly if she would return to the program without her friends, Isabella expressed uncertainty “I think, I ... maybe ... it depends. I think having my friends in robotics makes the experience better but I also just enjoyed being in robotics”.

Two of the five participants noted the importance of peer group participation for their initial enrolment in the ER program but have since developed an interest that extends beyond their peers. Olivia noted that working alongside her friends as teammates made her engagement within maker activity fun and when asked explicitly if she would return without her friends, Olivia answered “yeah, because I like it”. She had developed an interest in the activity that could exist without the co-participation of her peer group. Emily shared a similar perspective on the importance of her friends for her initial engagement but indicated she would continue to participate without them within her local program and went as far as to state she would engage within a similar group in other jurisdictions.

**The Perceived Deficit in Expansiveness**

One aspect of the study sought to explore how participants perceived their ability to join a similar program grounded in educational robotics, even another school group hosting a MATE-ROV club. Three of the five participants indicated they would not continue to engage in similar activity if they were to move to another school. Jessica noted that despite having participated over a three-year period and feeling comfortable within the program, she would not enroll in similar activity in another setting without her friends. Olivia also gauged her motivation based on the presence of pre-program friends and therefore decided that she would most likely not continue to engage in a similar program outside of her own school community. When asked explicitly, Olivia replied “If I knew people in robotics. If not, I probably wouldn’t feel comfortable”.

Chloe’s reservations were grounded in her perceived competency and whether her abilities met the standard of the new group. When asked explicitly about her potential comfort in participating with another ER group, Chloe replied:

> *If I were to leave this group and me, by myself, go off, I wouldn’t because I would feel more scared if I was to make a mistake and I would feel like they’re smarter than me. In this group, I know that we are all equal, on the same level.*

Chloe’s perspective highlighted the equal footing that newcomers share when entering educative maker programs and the comfort of co-participating with peers who were at her level. Isabella expressed a more open-minded perspective on transitioning into a parallel program. She explained that she would participate in a similar group depending on the participants. Ultimately, Chloe, Jessica, and Olivia remained attached to pre-existing relationships to support their sense of belonging and comfort. Isabella offered a similar perspective, but to a lesser degree.

Emily, on the other hand, said she would be comfortable joining a parallel program without the co-participation of her peer group or concern over who formed the ingroup of the other program. She explained that a parallel group would have participants that share her interest in the activity and knew that shared interests could make connections with a new peer group. Emily's perspective described her understanding that others engaged in similar activity would logically share interests with her and therefore foster a sense of membership.

Although participants described their identity to be dependent upon the support and presence of their co-participating peers, they were asked about their potential futures within the field. When asked explicitly "Have the skills you developed made you more open to a future in technical fields or STEM-related fields?", all five students foresaw no obstacles to potential aspirations in STEM. In the end, all five participants explained that their individual trajectories did not align with the robotics field due to personal preference rather than perceived inability.

**The Importance of a Terminal Activity**

The MATE-ROV competition was a terminal activity to end each season, an opportunity to interact with other school-based groups. Participants described the competition as a driving force that stimulated work ethic, interest and enjoyment in educational robotics. Though the competition had originally motivated her engagement, Olivia found enjoyment in the challenge it gave her on a personal level in terms of her skill development within the program. Isabella presented a similar connection to the importance of the competition but added that competing made her work harder in the program. For Jessica, "it makes building the robot much more fun knowing that we're going to go and compete". She emphasized the learning that is associated with her continued participation which, for her, held equal importance. Chloe underscored how competition aligned with her competitive nature thus becoming a trigger for her continued participation. She stated that competing added to the overall enjoyment of the program, paralleling the perspectives of her teammates Olivia and Isabella.

Olivia and Isabella framed the importance of competition as a glimpse at the real world. They articulated that their experiences at competition showed the importance of technological competency while also stimulating their interest in STEM-based activity. When explicitly asked to describe the success she experienced in robotics, Olivia stated "I learned how to wire a robot and understand a lot of it ... [I] learned how to work with people and drive the robot". She was the only participant to highlight skill development as an indicator of her success.

All five participants noted success at competition to be a motivational trigger for re-engagement in the program. Perspectives highlighted both the importance of externally measured success at competition with several participants also making connections with feelings of personal accomplishment. Chloe discussed her feelings of success within the robotics program, she measured success as the team's growth and capacity within the domain of robotics. The following statement illustrated Chloe's perspective on team accomplishment as a measure of success:

> *Before we even knew if we won or not, it was just an accomplishment compared to previous years. We had done so much. We didn't even need to win ... we knew that we were doing really well.*

Adopting a similar perspective to Chloe, Jessica associated their win at robotics to feelings of personal pride in her team, commenting "it also feels great when you're walking around knowing that you have a winning robot".

Participants were explicitly asked whether success had become a required element to stimulate their continued reengagement. Isabella highlighted that while success is certainly a motivational factor, she would still participate in the program without it. She offered the following reflection

> *I came back every year because we were succeeding ... last year we got the highest score out of everyone else in the province ... since we keep getting better and better each year, it makes me want to go back and do even better than the year before.*

When asked if the absence of competition would deter reengagement, each participant decided it had become a secondary factor to stimulate their interest but was still a meaningful part of the experience. But, observational data conflicted with perspectives expressed by three of the five participants in the study. Chloe, Emily, and Isabella stated the absence of competition would not determine their engagement within the program yet, when the group was unable to attend the MATE-ROV competition due to a scheduling conflict, their participation ended. In this instance, participation was heavily weighted on the opportunity for product demonstration.

**The Impact of the Prototypical Identity on Perceived Belonging**

When asked to describe the other teams that participated in the robotics competitions over the last three years, all five participants described them as predominantly male, knowledgeable, and falling within a known stereotype. Isabella acknowledged the prototypical ingroup, "I would say that they're mostly boys and they usually look like the stereotypical nerd. So, they usually wear glasses and they really look like they know what they're doing". Chloe expressed reservation regarding her presence amid such a homogenous group but noted that the presence of her friends gave her comfort. Per her description, the other teams seemed to know more and were better suited for the competition yet, by her own words, she admitted "I don't know how much I know compared to others. I've never talked, we never talk to people when we go out for robotics. So, I don't know what other people know". The perception that other teams were more knowledgeable based on their prototypical identity was corroborated by Isabella, Jessica and Olivia. Yet, like Chloe, none of the participants could explain why they perceived the other teams to be better or more suited for the technical activity especially since they were experiencing measurable success at competition.

When prompted to reflect on their participation at competition, all five students described feelings of deficiency once they left the comfort of their local program. All five described their team as being all-girl and each one also commented on their assumed inexperience at competition. They all noted how other teams and even event organizers mistakenly interpreted their atypical girl team to be less knowledgeable when compared to their male counterparts. This perception was illustrated when Jessica stated:

> *[The other teams] look like they know what they're doing, more so than us. People probably think that we are not as good as we actually are ... A lot of people at the competition can't believe that we are an all-girls team and probably don't see us as doing anything with robotics.*

Emily highlighted the error in their perceived in-experience when she highlighted that others would view their team as "no good" yet they earned the highest score at their most recent competition. To a similar effect, Isabella said

> *Sometimes we may look like we're inexperienced but that's not the case ... I really think it's a surprising factor for a lot of people because they think that just because we're girls, we aren't able to do the same things as the other teams but we usually excel.*

Participants noted feelings of comfort, acceptance, and belonging within their local maker community of practice but all five of the participants agreed that, amid the larger community of practice, their all-girl status existed in clear polarity to the prototypical identity they experienced.

## Discussion

Three distinct findings (F1-F3) have been drafted based on participant narratives and the thematic analysis of the richly descriptive data. The following section offers succinct findings statements paired with brief discussions.

### F1: Intragroup relationships foster a connected social identity that can support comfort and belonging

As participants reflected on their experiences, their narratives highlighted the importance of peer relationships for both their initial engagement in educational robotics and motivation to participate year-after-year. This finding aligned with Wenger's (2000) notion of a connected identity whereby community members build a sense of comfort and belonging on shared histories and experiences. Connections can also be made with Archer et al.'s (2015) work on science capital, whereby the girls felt a sense of belonging as their peer group valued the activity. In this sense, the peer group served as the social capital to strengthen confidence in ER abilities and support ER self-concept.

Participants described a sense of social cohesion when reflecting on their intragroup connections. Their collective narrative aligned with Turner's (1982) work on social identity where he emphasized the importance of intragroup relations. His work highlighted social cohesion as a critical component to the interdependency of group members. As participants described their feelings of being bound to each other and the emotional empathy that came from their collaboration, their narrative seemed to mention all characteristics described by Turner (1982): a perceived similarity, social cohesion, positive self-esteem, emotional empathy, cooperation, and uniform attitude.

Feelings of comfort amid the intragroup allowed participants to work within a safe context. They were allowed to fail forward, highlighting the safety net created by a close group. It was noted throughout the data that comfort was a critical component in taking risks, making mistakes, and adopting the norms and practices that seemed unfamiliar at initiation. While estrangement and underperformance due to fear of social repercussions was a theme noted by both Stewardson et al. (2018) and Sullivan and Bers (2019) in their VRC studies, there was no supporting data within this study. The intragroup relationship offered the supportive construct that Kim et al. (2018) described as an essential element to foster the development of self-esteem in STEM-based activity.

**F2: Connected identities do not automatically build a perceived capacity and belonging in comparable groups**

An overreliance on the intragroup relationship can create an imbalance in the development of social identity. Wenger's (2000) notion of expansiveness underscored that "a healthy identity will not be exclusively locally defined [but] will identify with broad communities that lie beyond direct participation" (p. 240). The data showed that despite a level of competency developed over a three-year-period and successful performance at intergroup competition, four of the five participants stated that they would not participate within a comparable program without the presence of their friends. Participants felt uncertain about their acceptance as they continually mentioned the need for their peers to be present. The overall narrative underscored an interesting connection between their description of a strong connected identity and their perceived deficit of their expansive identity.

The perception that other teams were more knowledgeable and better suited for robotics based on their gender highlighted a perceived deficit in the effective quality of participant identity. The perceived deficit in expansiveness highlighted a marked discrepancy between the limited identity that students described and that which they demonstrated through performance. Their narrative aligns greatly with the findings of the ASPIRES work as Archer et al. (2020) described trends for science self-concept to decline in girls around the age of the participants in this study.

The fear of incompetency and discomfort were the strongest reservations regarding the ability to participate in a comparable program, even one based upon the MATE-ROV framework. Kim et al. (2018) noted a similar trend where girls inaccurately rate their own competencies. Participant narratives described an uncertainty regarding their value and ability to contribute to other programs and subsequent peer groups. The risk of perceived underperformance aligns with Spencer et al.'s (2016) notion of stereotype threat. Participants worry about the relationship between their performance and acceptance.

**F3: Successful domain performance does not automatically reduce the impact of stereotype threat**

Participants were able to test the effectiveness of their social identity as they competed at an intergroup competition. Wenger (2000) noted that an effective identity supports engagement with neighbouring communities and the ability to perform in an intergroup context. The intergroup context gave participants an insight into the prototypical identity associated with educational robotics and similar technological activity.

Experiences within the intergroup context internalized a sense of estrangement despite the participants demonstrating a strong effectiveness through measured success. Yet, the stereotype threat within the context of this study did not result in underperformance as suggested by the literature (Sparks, 2017; Spencer et al., 2016, Steele, 1997). But, there was a sense of discomfort. Time on the podium did not seem to reduce the overwhelming presence of the prototypical identity in educational robotics though the work of Stewardson et al. (2018) on experiences in VRC would have suggested otherwise. Participant self-efficacy did not support the perception of similar successes in comparable ER groups. Spencer et al. (2016) highlighted the potential for stereotype threat to undermine feelings of comfort and belonging while also fostering a sensitivity regarding any sign of estrangement. They contended that "events that might seem innocuous to others, such as … receiving a disapproving glance from an instructor, may undermine … motivation and commitment to the domain" (p. 424).

Brown and Ross (1982) mentioned the potential for groups that experience a threat to their social standing to experience feelings antipathy towards the ingroup. Although the participants did notice the dominant boy group at competition, they never expressed any bad feelings towards them. Similarly, the participants did not mention any attempts to conform to the stereotype and suspend aspects of their own identity, a potential coping mechanism suggested by Sparks (2017). Participant narratives did highlight an awareness as to the 'geekish' nature of their counterparts, but there was no reference to their own adoption of a similar identity. If anything, they noted how they were different.

Overall, the findings challenged my assumptions regarding the social identity the participants had developed within their educational robotics experiences. I had assumed that a strong, connected identity paired with success at competition had built a balanced identity for the participants and placed them within Archer et al.'s (2015) high science capital category. But, from an analysis of the data, their perceived sense of comfort and belonging was still susceptible to stereotype threat. Feelings of estrangement and limited ER self-concept were noted across the narratives of the study participants. A noted discrepancy emerged between the articulated expansive / effective deficit of participants and the successes experienced at competition. This finding underscored the importance of supportive structures to prepare participants for intergroup contexts even when experiencing achievement within the domain. Within the context of this study, students were motivated to disconfirm the negative stereotype and were successful. Yet, lingering feelings were articulated in relation to their discomfort. Stereotype threat continues to represent an obstacle for identity development as there remains the potential for underperformance within the added pressure to succeed.

## Conclusion and Implications

Educational robotics programs such as MATE-ROV offer students early exposure to STEM-based experiences. The girl participants of this qualitative study participated in ER with marked success and no attrition. Their narratives spoke of a strong sense of connectedness and social cohesion within their immediate group, their narratives spoke of success at intergroup competition – all aspects to suggest a high level of STEM capital. Yet, there was consistent reservation when prompted to reflect on comfort and belonging within comparable groups. The findings of this study highlighted the importance of intragroup relationships as social capital in the development of a connected identity while acknowledging the stereotype threat and limited expansiveness felt by the participants.

Implications for ER groups – or similar STEM-based programming - are to explicitly prepare girl participants to work within the boy-dominated field by creating a context where both genders converge. Not all programming has access to large-scale competitions like VEX and MATE-ROV, so similar experiences must be created. Constructs could be embedded at the organizational level of programs such as MATE-ROV to address the trend in perpetuating the perception that boys form the prototypical identity associated with technical fields in robotics and similar. But, it must also me noted that efforts to simply girlify aspects of the programming can also be counterproductive. A balanced approach must be struck.

A known concern regarding case study findings is the ability to make generalization applicable to other contexts. The small sample size for this study allowed for a more comprehensive and in-depth exploration of each of the 5 participants experiences. The homogeneity of the group has also given the study a deeper understanding of a subgroup of the larger population. As ER competitions have grown in popularity on a global scale, small generalizations can be made for any program offering built upon comparable experiences in robotics.

Future research may extend on the findings of this study by exploring the narratives of groups engaged in MATE-ROV in other schools. Similarly, an exploration of experiences in comparable programs that offer STEM-based activity may offer a balanced perspective on social identity development, feelings of comfort and belonging, and the retention or attrition of program participants. Competition offers a unique experience of intergroup play which can be the basis for future research regarding stereotype threat and the experiences of other marginalized groups.

## References

Allen, C., & Eisenhart, M. (2017). Fighting for desired versions of a future self: How young women negotiated stem-related identities in the discursive landscape of educational opportunity. *Journal of the Learning Sciences, 26*(3), 407-436. https://doi.org/10.1080/10508406.2017.1294985

Archer, L., Dawson, E., DeWitt, J., Seakins, A., & Wong, B. (2015). “Science Capital”: A conceptual, methodological, and empirical argument for extending Bourdieusian notions of capital beyond the arts. *Journal of Research in Science Teaching, 52*(7), 922–948. https://doi.org/10.1002/tea.21227

Archer, L., Moote, J., Macleod, E., Francis, B., & Dewitt, J. (2020). ASPIRES 2: Young people’s science and career aspirations, age 10-19. London: UCL Institute of Education.

Bevan, B. (2017). The promise and the promises of making in science education. *Studies in Science Education, 53*(1), 75-103. https://doi.org/10.1080/03057267.2016.1275380

Bloomberg, L. D., & Volpe, M. (2016). *Completing your qualitative dissertation: A road map from beginning to end*. Thousand Oaks, CA: SAGE Publications.

Brancalião, L., Gonçalves, J., Conde, M. Á., & Costa, P. (2022). Systematic Mapping Literature Review of Mobile Robotics Competitions. *Sensors (Basel, Switzerland)*, *22*(6), 2160–. https://doi.org/10.3390/s22062160

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77-101. https://doi.org/10.1191/1478088706qp063oa

Brown, R., & Ross, G. (1982). The battle for acceptance. In H. Tajfel (Ed.), Social Identity and Inter Group Relations. Cambridge: Cambridge University Press. 15-40

Cano, S. (2022). A Methodological Approach to the Teaching STEM Skills in Latin America through Educational Robotics for School Teachers. *Electronics (Basel)*, *11*(3), 395–. https://doi.org/10.3390/electronics11030395

Flyvbjerg, B. (2011). Case study. In N. Denzin & Y. Lincoln (Eds.), The SAGE handbook of qualitative research (pp. 1382-1455). Thousand Oaks, CA: SAGE Publications.

Goreth, S., & Vollmer, C. (2023). Gender does not make the difference: Interest in STEM by gender is fully mediated by technical socialization and degree program. *International Journal of Technology and Design Education*, *33*(4), 1675–1697. https://doi.org/10.1007/s10798-022-09772-z

Hernandez, P. R., Bloodhart, B., Barnes, R. T., Adams, A. S., Clinton, S. M., Pollack, I., . . . Fischer, E. V. (2017). Promoting professional identity, motivation, and persistence: Benefits of an informal mentoring program for female undergraduate students. *PLoS One, 12*(11). https://doi.org/10.1371/journal.pone.0187531

Kim, A., Sinatra, G. M., & Seyranian, V. (2018). Developing a stem identity among young women: A social identity perspective. *Review of Educational Research, 88*(4), 589-625. https://doi.org/10.3102/0034654318779957

Merriam, S. B., & Tisdell, E. (2016). *Qualitative research : A guide to design and implementation*. San Francisco, CA: Jossey-Bass.

Miles, M. B., Huberman, A. M., & Saldana, J. (2014). *Qualitative data analysis: A methods sourcebook*. Los Angeles, CA: SAGE Publications.

Ryan, G., & Bernard, R. (2003). Techniques to identify themes. *Field Methods, 15*(1), 85-109. https://doi.org/10.1177/1525822X02239569

Sparks, D. (2017). Navigating stem-worlds: Applying a lens of intersectionality to the career identity development of underrepresented female students of color. *Journal for Multicultural Education, 11*(3), 162-175. https://doi.org/10.1108/JME-12-2015-0049

Steele, C. M. (1997). A threat in the air. How stereotypes shape intellectual identity and performance. *The American psychologist, 52*(6), 613-629. https://doi.org/10.1037/0003-066X.52.6.613

Spencer, S. J., Logel, C., & Davies, P. G. (2016). Stereotype threat. *The Annual Review of Psychololgy, 67*(1), 415-437. https://doi.org/10.1146/annurev-psych-073115-103235

Stewardson, G. A., Robinson, T. P., Furse, J. S., & Pate, M. L. (2019). Investigating the relationship between VEX robotics and student self-efficacy: an initial look. *International Journal of Technology and Design Education, 29(*4), 877–896. https://doi.org/10.1007/s10798-018-9461-4

Sullivan, A., & Bers, M. U. (2019). Vex robotics competitions: Gender differences in student attitudes and experiences. *Journal of Information Technology Education, 18*, 97–112. https://doi.org/10.28945/4193

Turner, J. C. (1982). Towards a cognitive redefinition of the social group. In H. Tajfel (Ed.), *Social Identity and Inter Group Relations*. (pp. 15-40) Cambridge: Cambridge University Press.

Watermeyer, R. (2012). Confirming the legitimacy of female participation in science, technology, engineering and mathematics (stem): Evaluation of a UK stem initiative for girls. *British Journal of Sociology of Education, 33*(5), 679-700. https://doi.org/10.1080/01425692.2012.678751

Wenger, E. (2000). Communities of Practice and Social Learning Systems. *Organization, 7*(2), 225–246. https://doi.org/10.1177/135050840072002

Yin, R. K. (2014). *Case study research : Design and methods*. Thousand Oaks, CA: SAGE Publications.

Zuhrie, M., Buditjahjanto, I. G. P. A., Nurlaela, L., & Basuki, I. (2021). Do educational robotics competitions impact students' learning? *Journal of Physics: Conference Series, 1810*(1), https://doi.org/10.1088/1742-6596/1810/1/012045

Design and Technology Education: An International Journal

28.2

# A framework for analyzing technological knowledge in school design projects including models

**Björn Citrohn, Linköping University, Sweden**

## Abstract
This study investigates, and further develops, a framework for analyzing technological knowledge emanating from school design projects; a framework that has the potential to be used as a tool for teachers when choosing and planning design projects. The study also intends to answer the research question: What technological knowledge, associated to physical models, emanates from design projects common in Swedish secondary schools. To answer the research question, the framework is used to analyze three design projects common in Swedish secondary schools. The design projects were video-recorded during actual classroom work by using a self-following robot camera. The projects involved three teachers and 70 students in grades 7, 8 and 9. Deductive content analysis of the video-recordings revealed that technological knowledge from four categories – Technical skills, Technological scientific knowledge, Socio-ethical technical understanding and Engineering capabilities – within the framework emanated from the three projects. A new category of technological knowledge was also found, namely Technological research capabilities. This fifth category is related to the capability to search for, and interpret, information about solutions when doing a design. An implication of the conducted study is that design projects are important to enable development of technological knowledge in the school subject technology. However, considering the amount of time a design project requires, there is only room for a few projects in secondary school. Therefore, technology teachers have to carefully choose and combine projects to educate technological literate citizens as well as prepare students for studies and future careers within engineering and technology.

## Keywords
Technological knowledge, Models, Design projects, Technology Education.

## Introduction
Technology can be defined as the use or the making of artefacts (Mitcham, 1994). Artefacts are produced as the result of design processes, in which technological knowledge is important (de Vries, 2005). Thus, technological knowledge, with a focus on the ability to design artefacts, is important to the curricula in many countries (Norström, 2015). To cater for these curricula aims it is customary for teachers to carry out design projects in their classes to develop the technological knowledge students use in design. Thus, it could be beneficial for teachers and the development of technology education to investigate common school design projects, and the technological knowledge that emanates from them.

In order to perform a study of design projects, definitions of concepts being used are important since the definitions might be different in a school context than in other contexts. A *design project* is an activity whereby students develop a technological solution to a problem. This problem is often presented by the teacher. The solution is often presented in the form of a physical model, which is supposed to be presented, or tested, at the end of the project. Models can be used to analyze and evaluate solutions with regards to the goals and intended functions stated in the problem (de Vries, 2005). In the context of this study a *model* is a physical model, built using everyday materials that represent the final product, but is simpler and lacks many features compared with the intended final product (Citrohn et al., 2022). Thus, the *final product* is often a thought product that the students are, sometimes, supposed to be able to describe using their physical model, sketches, or drawings. To create the model a design process is used. A *design process* is defined as a process whereby students develop and test ideas for the solution of a technological problem using a model of a final product.

In Sweden, teachers have considerable freedom to design their teaching as long as the learning outcomes specified in the national curricula are met. Thus, teachers of technology are free to choose which design projects they want to use in their classes, giving them great freedom in planning. At the same time, this freedom constitutes a challenge for the teachers in planning and choosing suitable projects that will effectively develop students' knowledge. In Sweden, about 200 hours (from grade 1 to 9) is allotted to the teaching of technology. Thus, there is a limit to the number of projects that can be carried out throughout secondary school years. Hence, teachers must choose design projects carefully and wisely. For this reason, it would be helpful for many teachers to have a tool for evaluating design projects to assess the technological knowledge deriving from a project.

There are very few studies, in particular empirical ones, that address technological knowledge arising from school design projects. Design projects are quite open-ended regarding what technical knowledge actually becomes available for the students. This is another argument for conducting this study. Citrohn et al. (2022), in an empirical study, concluded that the opportunities for technology learning in relation to models very much depend on a project's presumptions and openness. Furthermore, Christiaans and Venselaar (2005) and Esjeholm (2015) concluded that limited technological knowledge constrains students' ability to be creative and to produce genuine solutions. Rauscher (2010), however, found that on one hand knowledge is indeed needed for design activities, but on the other hand the same design activities are also knowledge-generating.

The aim of this study is to evaluate a framework designed for analyzing technological knowledge in education. The framework will be applied to three design projects, representative of Swedish schools. To examine and further develop the framework as a tool for teachers in the choosing and planning of design projects, the following research question is examined:

What technological knowledge, associated to physical models, emanates from design projects common in Swedish secondary schools?

**A framework for analyzing knowledge in technological education**

Based on knowledge traditions, Nordlöf et al. (2022a) have designed a heuristic framework for analyzing knowledge in technology education. However, according to Norström (2014), Swedish technology teachers' perceptions of what constitutes technological knowledge varies considerably. Taking this as a point of departure, Nordlöf et al. (2022b) used their framework (Nordlöf et al., 2022a) to design an interview-study investigating technology teachers' perceptions of technological knowledge. They found, empirically, two new categories (Nordlöf et al., 2022b) in addition to their original framework (2022a). This new expanded framework is used for analyzing the data in this study and is displayed in Table 1.

Other frameworks for analyzing technological knowledge exist (see DiGironimo, 2011) and Mitcham, 1994). However, they were not designed with technology education in mind. For this reason, the framework developed by Nordlöf et al. (2022a, 2022b) is chosen for this study. It should be noted, indeed, that Nordlöf et al. (2022a) applied the framework, with promising results, to the English syllabus for Design and Technology and Swedish curricula for Technology.

The framework consists of five knowledge categories. The first three: Technical skills, Technological scientific knowledge, and Socio-ethical technical understanding, each represent a section of technology education and knowledge traditions. The other two, Engineering capabilities and Civic capabilities, are based on perceptions of teachers. Table 1 displays the five categories, their knowledge-origin, knowledge-use and knowledge-activities.

***Table 1. The framework from Nordlöf et al. (2022a, 2022b)***

| Knowledge categories | Knowledge-origin | Knowledge-use | Knowledge-activities |
|---|---|---|---|
| **Technical Skills**<br>- knowledge *within* technology. | Craftsmanship and other experience-based knowledge traditions. Justified by experience and trial and error. | Taught in crafts and technical education. Craftsmen and technicians. | Making<br>Sketching<br>Drawing<br>Measuring |
| **Technological scientific knowledge**<br>- knowledge *within* technology. | Engineering and science knowledge traditions. Justified with scientific methods, although standards and practices are foundations. | Taught in engineering education.<br>Engineers. | Analyzing<br>Calculating<br>Describing<br>Documenting<br>Engineering drawing |
| **Socio-ethical technical understanding**<br>- knowledge *about* technology | Humanities and social sciences knowledge traditions. Justified by research methods. | Teach students to discuss and relate to different aspects of technology. | Describing<br>Comparing over time<br>Analyzing<br>Evaluating |
| **Engineering capabilities**<br>- how knowledge is used and practiced | Teachers' perceptions of knowledge in technology education. | Prepare students for further studies and work within engineering. | Engineering thinking<br>Project running |
| **Civic capabilities**<br>- putting knowledge into a context. | Teachers' perceptions of knowledge in technology education. | Prepare students for life in a technical world. | Decision making |

### Technological knowledge in relation to the framework

To understand the framework of Nordlöf et al., the categories of knowledge are examined in relation to the philosophy of technology. The technology philosophers Mitcham and De Vries are important to technology education in Sweden. For this study, Mitcham's knowledge aspects of technology (1994) and De Vries artefact-related knowledge (2006, 2019) are the most important.

Mitcham (1994) defines four aspects of technology: Artefacts, Knowledge, Activity and Volition. Within the aspect of Knowledge, most relevant for this study, Mitcham describes four types of technological knowledge: *Sensorimotor skills* or *know-how* is about making and using artefacts.

Knowledge is often acquired intuitively and by trial and error, learning or apprenticeship. *Technical maxims* are the articulating of successful making of knowledge, such as rule of thumb and recipes. *Descriptive laws* refer to knowledge based on experience. *Technological theories* describe knowledge within applied science, for example aerodynamics is an application of thermodynamics and fluid mechanics. Mitcham's four types of knowledge correspond with and support the first two categories, Technical skills and Technological scientific knowledge, in the framework of Nordlöf et al. (2022a, 2022b). Two examples from technology education are design processes and programming, such as following recipes; thus knowledge is based on Technical maxims. Another example is students' learning about making constructions strong and stable, which is knowledge based on Descriptive laws as well as Technological theories.

Technological knowledge is also discussed in engineering philosophy, which could be regarded as a sub-disciple of the philosophy of technology (Mitcham, 1994). Engineering philosophy is normative, giving artefacts a functional as well as a physical nature (De Vries, 2019) that is connected to four different types of artefact-related knowledge (De Vries, 2006). *Knowledge of the physical nature* is about the material properties of the model. *Knowledge of the functional nature* is about the models' functions. *Knowledge of the relations between physical and functional nature* is about suitability of materials for certain functions in models or artefacts. *Knowledge of processes* is about working principles that turn structure into function. Thus, knowledge about the properties a structure might have or is desired to have.

The knowledge-types are relevant for the present study, when examining a project's technological knowledge associated to physical models. For example, students are often required to develop and present a physical model at the end of a design project. When constructing models, students often build them using everyday materials, simpler than the final product. Nevertheless, the model is often supposed to display functions and structures of the final product. In several countries' technology curricula, knowledge of both physical and functional natures of models and knowledge of the relations between them are present. Thus, students are to learn about technological solutions as well as adapting them for expediency. The Swedish curriculum for technology expresses this as "knowledge of technical solutions and how constituent parts work together to achieve expediency and function" (Skolverket, 2021, p1).

## Method

This study uses a qualitative methodological approach through a deductive content analysis (Mayring, 2004; Elo & Kyngäs, 2008; Hsieh and Shannon, 2005). Video-recordings from technology classrooms in three Swedish secondary schools were used as primary data. All teachers in the studied classrooms were licensed and experienced, each one carrying out a design project with their students. The projects were chosen to get a variety of different types of projects and because they were seen as being representative of Swedish technology education in compulsory school education. The three projects, named as the *Bridge project*, the *Pedometer project* and the *Greenhouse project*, are described in detail below.

To record activities in the classroom, an iPad was used as a video recording device. For recording of sound, microphones worn by teachers were used. At the same time, these microphones worked as detectors that were followed by a robot on which the iPad was mounted. Thus, when teachers moved around the classroom, the robot targeted the iPad in the direction of the teacher and made sure s/he was followed and video-recorded.

***Table 2. Overview of the different project recordings***

| Project | Recorded lessons | Total lessons in the project | Total minutes of recordings used in the analysis | Grade and number of students |
|---|---|---|---|---|
| Pedometer project | 2 | 8 x 60 min + spare time for students | 95 | Grade 8<br>23 students |
| Greenhouse project | 2 | 10 x 60 min | 110 | Grade 9<br>24 students |
| Bridge project | 2 | 8 x 50 min | 35 | Grade 7<br>23 students |

The video recordings had excellent audio quality and the visual recordings of the teachers were also good. The quality of the recording of students' activities depended on the microphone the teacher was wearing, and that the camera followed the teacher's movements in the classroom. Thus, when the teacher was in close proximity to the students, the audio and video recordings were good. This means that the microphone and camera picked up some talk and actions from students when they were near the teacher, even if they were not involved in a direct conversation with them. Disadvantages of using a robot are not being able to correct malfunctioning of the camera but also, not being able to care about the integrity of people being recorded. For instance if, people not intended to be recorded, are entering the classroom during recording. Next, the content and aims of the projects are described.

**The Bridge project**

In the Bridge project, performed in grade 7, groups of four students were involved in designing a suspension bridge. The bridge was supposed to have a span of 24 centimetres, support a weight of 700 grams for 10 seconds and at the same time weigh as little as possible itself. Prior to the project, the students worked with structures and materials, thus developing theoretical knowledge on making constructions strong and stable. The Bridge project covered in total of eight lessons of 50 minutes each, and during the whole project students had access to weighing equipment to test their bridges. Before starting to build and test their bridge, students' ideas for construction were to be demonstrated to the teacher in a drawing. At the end of the project, before the teacher tested their bridges, the students were supposed to explain and justify their choices of materials and structure. Students had access to materials such as ice-cream sticks and lolly-pop sticks. Furthermore, they had access to tools such as glue-guns, knives, pliers, and saws. When all bridges were tested, the students were asked to evaluate the different groups' bridges from a constructional point of view using their theoretical knowledge. In the final lesson, students were asked individually to present an analysis of their groups' bridge in comparison with the winning bridge, to learn from mistakes. During the project, the students were also required to document progress, sketches, and drawings in their logbooks.

**The Greenhouse project**

In the Greenhouse project, the students, in groups of four, were asked to design a miniature greenhouse where different functionalities were supposed to be controlled by a micro:bit. The micro:bit was supposed to regulate temperature, light, and moisture by using sensors to give signals to control the lightbulbs, windows, and water systems. The groups of grade 9 students had ten 60-minute lessons to finish their greenhouse. The given task from the teacher was that the greenhouse should be able to keep small plants in good conditions. Few of the students had prior knowledge about programming. At the end of the project, the students were supposed to display their greenhouse and explain and demonstrate functions to the class and the teacher. When constructing the greenhouse, they were able to use rolled office-paper as frames and transparent plastic as glass. At the introduction lesson, the teacher showed how to construct the frames and in the second lesson she demonstrated a variety of everyday materials that could be used in the construction. Moreover, the students also had access to small electric engines, servo motors, LEDs, and other electrical components when constructing different functions. The tools available included scissors, glue guns, pliers and knives. All students had logbooks in which they were asked to write down reflections on their own as well as the groups' processes.

### The Pedometer project

In the Pedometer project, the students were, individually, asked to construct a pedometer controlled by a micro:bit. The aim was to construct a model of a pedometer, which was to inspire younger students to walk 10,000 steps per day. An important requirement of the project was adapting the product for sustainability and renewability. They were told, in order to give the project more authenticity, that the model would be evaluated by stakeholders from the Swedish National Board of Health and Welfare. At the end of the project, there was supposed to be an exhibition in which all students were to market their intended final product, the pedometer, by using their model to the stakeholders that in fact were teachers. The grade 8 students had 12 60-minutes lessons to construct the model. Some students had experience of programming and all of them had worked with control and regulation in grade 7. Before starting the project, the students had worked with design and product development theory. When constructing, they had access to materials such as cardboard, wooden sticks, glue, textile cord, plastic, and small metal pieces. They also had access to tools such as scissors, glue guns, pliers and knives, and were asked to write notes and draw sketches in logbooks.

## Analysis

The analysis used in this study can be described as a deductive content analysis following the process as defined by Elo & Kyngäs (2008). The process can include testing of existing concepts and categories, as well as sub-categories describing the content of the categories (Marshall & Rossman, 1995). Before starting the Elo & Kyngäs (2008) process, video recordings were made as described above. The first step in the analysis process is the preparation phase, where the researcher familiarized himself with the recordings to get an overview of the material. As parts of the video recordings were made without the researcher being present, this was an important step. The next step was to develop a categorization-matrix based on the framework of Nordlöf et al. (2022a, 2022b). A part of the first categorization matrix is displayed in table 3.

***Table 3. Parts of the first categorization matrix used to analyze the data***

| Knowledge categories with description | Bridge project | Greenhouse project | Pedometer project |
|---|---|---|---|
| Technical Skills<br>Craftsmanship or other types of experience-based knowledge traditions. Justified by experience and trial and error. Making, sketching drawing, measuring | | | |
| Technological scientific knowledge<br>Knowledge… | | | |
| Socio-ethical technical understanding<br>Knowledge… | | | |
| Engineering capabilities | | | |
| Civic capabilities | | | |

The next steps were revisiting the data, searching for episodes and actions displaying the technological knowledge gained from the projects. In order to explain how the categorization-matrix was used, a part of the matrix and some examples of episodes are displayed and coded in table 4. In this example, the episode, was categorized as *Technical skills* since it involved making, and using trial and error.

***Table 4. Excerpt from an episode categorized as displaying technical skills***

| Framework (Nordlöf et al.) | The Greenhouse project - |
|---|---|
| Technical Skills | -You are to make a model, in which you can control the temperature. (Teacher)<br>Action:<br>Students are making openable hatches, in the model, using trial and error. |

After categorizing all episodes, it was clear that the category *Civic capability* was not present in the analyzed data. The next step, after excluding the category of Civic capability, was to refine the categorization-matrix by creating sub-categories that would provide more fine-grained descriptions of the knowledge derived from the projects. The category of Technical skills was, for example, refined into four sub-categories: Model building, Sketching and drawing, Programming, and Carrying out a design process. Technological scientific knowledge was refined into two sub-categories: Construction techniques and materials and Sensors and controllers. Socio-ethical technical understanding was refined into Effects on human and environment. Engineering capabilities was refined into Running projects from idea to marketing. Finally, knowledge specifically related to the projects was pinpointed, leading to descriptions such as 'testing functions using trial and error'; see table 5.

***Table 5. Part of the refined categorization matrix. Black fields represent a knowledge category being present within the recordings***

| **Technical skills** | Bridge project | Greenhouse project | Pedometer project |
|---|---|---|---|
| Model building | | | |
| - testing functions using trial and error | | | |

Although the framework of Nordlöf et al. (2022a, 2022b) was used as a point of departure in the analysis, an open mind was kept for new categories of knowledge emerging from the data. This resulted in a new category, *Technological research capabilities*, being introduced to the analysis. This category is about developing knowledge by searching and interpreting technological information that is deemed to be of use to achieve a solution to the design task. As there is a vast amount of information on the Internet related to programming and construction, there is a need for knowledge about how to sift through this information to find what can be applied to the task at hand. Moreover, within the projects, students were also able to develop this knowledge, as they could compare their design solution with solutions on similar problems presented on the Internet. Table 6 displays examples of episodes related to this category.

***Table 6. Examples of episodes categorized to demonstrate Technological research capabilities***

| Knowledge | Bridge project | Greenhouse project |
| --- | --- | --- |
| Technological research capabilities | *- We are searching the Internet for solutions and comparing them to our model. (Student)*<br>Action:<br>*Students are comparing their model to applicable solutions on the Internet.* | *- I can help you when googling for applicable programs. (Teacher)*<br><br>Action:<br>*Students are searching the Internet for applicable programs.* |

**Ethical considerations of the study**

This study follows the ethical guidelines of the Swedish Research Council (Vetenskapsrådet, 2017). The teachers and students were given information about the project and written consent was given before the recordings. The teachers and students could at any point withdraw from the study. Students not wanting to participate in the study were placed in the back of the classroom, out of sight of the camera. The study, registered at Linköping University's personal data processing unit, was pseudonymized to ensure anonymity. The pictures in this study are snapshots from the video recordings and are used with permission of the teachers and students.

## Results

The analysis resulted in five categories of technological knowledge, each one consisting of sub-categories arising from the projects. An overview of the knowledge is displayed in table 7. Black fields represent a knowledge category being present within the recordings.

In the following section, the different knowledge types are described in more detail and exemplified using pictures from the recordings of actions, as well as excerpts from conversations, in order to support the understanding of the categories used.

***Table 7. Knowledge deriving from the projects; black fields represent a knowledge category being present within the recordings***

| **Technological Knowledge** | Bridge project | Greenhouse project | Pedometer project |
|---|---|---|---|
| **Technical skills** | | | |
| Model building | | | |
| - testing constructions using trial and error | ■ | ■ | |
| - testing functions using trial and error | | ■ | ■ |
| - discussing solutions | ■ | ■ | |
| - displaying intentions of a final product | | | ■ |
| Sketching and drawing | | | |
| - designing solutions | ■ | ■ | ■ |
| - discussing solutions | ■ | ■ | |
| - documenting solutions | ■ | ■ | ■ |
| - displaying intentions of a final product | | | ■ |
| Programming | | | |
| - controlling functions in solutions | | ■ | ■ |
| Performing a design process | | | |
| - finding solutions to technological problems | | ■ | ■ |
| **Technological scientific knowledge** | | | |
| Construction techniques and materials | | | |
| - choosing material for model | | ■ | ■ |
| - choosing material for final product | | | ■ |
| - building strong, stable and lightweight constructions | ■ | ■ | |
| Sensors and controllers | | | |
| - demonstrating functions in technological solutions | | ■ | ■ |
| - connecting and controlling micro:bits and sensors | | ■ | ■ |
| **Socio-ethical technical understanding** | | | |
| Effects on human and environment | | | |
| - adapting sustainability and renewability for solutions | | | ■ |
| - adapting solutions for impacts on emotions | | | ■ |
| **Technological research capabilities** | | | |
| Searching for and interpreting technological information | | | |
| - finding and comparing constructional solutions | ■ | ■ | ■ |
| - finding and interpreting programming solutions | | ■ | ■ |
| **Engineering capabilities** | | | |
| Running projects from idea to marketing | | | |
| - developing from idea to final product | | | ■ |
| - evaluating and discussing constructional solutions | ■ | | |
| - marketing final product using a model | | | ■ |

**Model building**

All projects displayed signs of technical skills in Model building. In the Bridge project, models were mainly used for trial and error when optimizing material use to minimize the weight of the bridge while still being able to support the predetermined load (figure 1). The students observed and discussed weak points and inaccuracies in the model when loading the bridge. If the bridge held, they tried to remove materials in order to minimize its weight (figure 2).

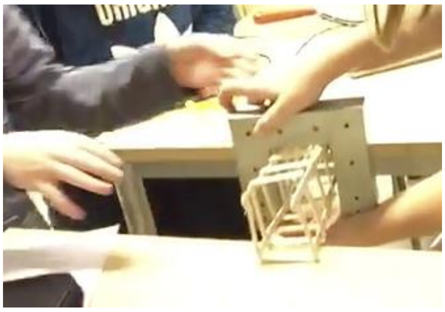


***Figure 1. Students loading model in order to test stability.***

***Figure 2: Student optimizing weight of the model by removing material.***

In the Greenhouse project models were used for trial and error when building the framework for the greenhouse. The students tried the stability of different framework constructions. The models also were used when testing functions using trial and error. This could be about testing functions such as opening windows or doors automatically when the temperature got too high.

In the Pedometer project students also used their models when *displaying functions of an intended final product;* for example, displaying an exclusive bracelet, by using everyday materials, supposed to be used in the final product. This demonstrated technical skills in displaying size, functions and materials of the intended final product using models of everyday materials.

**Sketching and drawing**

All projects let the students practice their skills within sketching and drawing when *designing* and when *documenting solutions*. In the Bridge project, that skill was in discussions both between students (figure 3) and between teacher and students. For example, the discussions could be about the structure of the model, and where support in the form of additional materials was needed.

***Figure 3. Students discussing by using sketches***

The teacher in the Greenhouse project used the opportunity to emphasize and discuss drawings and sketches when introducing the project:

> *The difference between a drawing and a sketch? The drawing is to be made in scale having measurements, showing what it would look like if it was a full-scale greenhouse. (The teacher in Greenhouse project project)*

In the Pedometer project, students used sketches and drawings when *displaying intentions in the final product.* Thus, the project let students develop skills in using a physical model as well as in making sketches and drawings in order to explain solutions to the final product.

**Programming**

Both the Greenhouse project and the Pedometer project let the students practice their technical skills in controlling functions in solutions, mostly by using trial and error. Students were programming in a computer and sending the program to the micro:bit for testing different functions within the model. For example, a group of students wanted to control the temperature in their greenhouse by using a programmed micro:bit. When the temperature got too high, the temperature sensor in the micro:bit switched on a fan in the ceiling of the greenhouse. In order to try out the program they had created, the students transmitted their program from their computer into the micro:bit. Then they were able to try out the function by using trial and error. If the program didn´t work, they had to reprogram it on their computer, transmitting it again to the micro:bit for testing in the model. The projects also displayed signs of knowledge about optimizing programs using variables and loops. In the Pedometer project, the teacher urges students to use loops when programming.

> *If we are to program every step from 1 to 10,000 it will be a lot of programming! Instead, we create a variable. Then we have a little box in which we can insert information. When we shake the micro:bit once we want the content of the box to increase by one. Now we have something that counts steps in an easy way. (Teacher in the Pedometer project)*

**Performing a design process**

A design process was carried out in the Pedometer and Greenhouse projects to find solutions to the projects' design tasks. In the Pedometer project, students applied theoretical knowledge about design processes to a real project, while in the Greenhouse project, knowledge about design processes was quite vague among students, leading to a more intuitive use of a design process. In both projects, but especially in the Pedometer project, the design process was used as a recipe. The students were asked to use a predetermined “design wheel” consisting of five steps, which they were required to follow when designing the Pedometer project.

**Construction techniques and materials**

The Bridge project let students practice knowledge about *building a strong, stable and lightweight construction* with predetermined materials. The project wasn´t only about building a model but about students using and developing their knowledge about construction techniques. At the end of the project, the students also evaluated and analyzed the construction of the winning bridge by applying their knowledge about construction and materials. This was emphasized by the teacher when introducing the project:

> *Your analysis is important. There you use your skills that you have learned in theory to analyze your own and other people's bridges. What was it about the winning bridge that made it possible to build it both strong and light? (Teacher in the Bridge project)*

The Pedometer and Greenhouse projects let students practice their technological scientific knowledge about construction techniques and materials when *choosing material for the model*. In the Pedometer project, the students also chose materials for the final product, being gaining even more Technological scientific knowledge.

**Sensors and controllers**

Knowledge about sensors and controllers were, for obvious reasons, displayed in both the Pedometer and Greenhouse projects when *connecting and controlling micro:bits and sensors* and when *demonstrating functions in technological solutions.* An interesting example of this was displayed in the Greenhouse project. The teacher instructed the students to use one function in the micro:bit to display another function. For example, the temperature sensor was supposed to be used to switch on a light or a heater when temperature was too low. However, it turned out to be difficult to test this function since the temperature in the classroom was quite constant. Instead, the teacher suggested students used the light sensor in the micro:bit to test the function of the temperature sensor. The project also let students practice knowledge about micro:bit connectors and sensors, as well as artefacts such as motors, propellers and LEDs that could be controlled by the micro:bit.

**Effects on humans and environment**

The only project offering knowledge about socio-ethical technical understanding was the Pedometer project. One student was designing a pedometer as a bracelet and *adapting technological solutions to achieve impact on emotions.* Her intention was to have holes for the pin in the strap of the bracelet. She argued that people with wide wrists could be identified, by using that solution. Instead, she chooses to construct a bracelet with Velcro (see figure 4. The Pedometer project also let students practice their knowledge of *adapting for sustainability and renewability in technological solutions*, since this was a requirement of the project.

*Figure 4. Student-built Pedometer as a bracelet*

**Searching for and interpreting technological information**

Technological research capabilities were displayed in all projects when *finding and comparing constructional solutions*. In the recordings, it could be seen that students compared their own models of their bridge with real-life bridges found on the Internet. Students actually held their bridge beside the picture of a real-life bridge in order to compare constructions. The Pedometer and Greenhouse projects also let students practice their research capabilities when searching for, and interpreting, information about programming of the micro:bit.

**Running projects from idea to marketing**

Engineering capabilities were present in the Pedometer project, as the students were to *marketing final product by using a model* to a group of stakeholders during an exhibition. The students were asked to communicate their final product to stakeholders by using a model, practicing their engineering capabilities when 'translating' technological solutions to the stakeholders, as well as running a project from idea to product. Thus, students had to use everyday language to describe their technical solutions when marketing. Furthermore, one of the aims of the project was, according to the teacher, to gain insight into the work of an engineer.

## Discussion

The aim of this study was to evaluate and develop a new framework for analyzing technological knowledge. The new framework was intended to be used as a tool for teachers when selecting and planning design projects to perform in their classes.

The study fills a knowledge gap about students' technological knowledge arising from school design projects. Studies from Christiaans and Venselaar (2005) and Esjeholm (2015) examine how students' technological knowledge affects their ability to create solutions in design projects. The present study examines the technological knowledge emanating from school design projects, thus providing information about how design projects could affect students' technological knowledge. The present study also supports the results from Citrohn et al. (2022) and Rauscher (2010), which concluded that the opportunities for technology learning very much depend on the project, and that design activities are also knowledge-generating.

The data consists of only three projects in Swedish schools. However, the recordings involve 70 students and three teachers, and consists of about five hours of actual classroom work. Moreover, the projects are representative of Swedish technology education and familiar in secondary schools. The framework used to analyze the projects (Nordlöf et al., 2022) might be considered a general framework for technology education. However, Nordlöf et al. (2022) used the framework for analyzing parts of curriculars containing *Design*, which worked very well. Therefore the framework is relevant and usable for analyzing design projects.

**The usability of the examined framework**

The framework of Nordlöf et al. (2022a, 2022b) was found to be useful for studying technological knowledge associated to physical models in design projects, and hence was useful for answering the research question. The framework thus proved to be useful for investigating design projects commonly found in compulsory schooling.

The present study argues that Civic capabilities are a knowledge category overarching the others in this study. When Nordlöf interviewed teachers about technological knowledge, they defined *Civic capabilities* as knowledge preparing students for life in a technical world (Nordlöf et al., 2022b). This is consistent to one of the aims of the Swedish curricula for Technology (Skolverket, 2021). Also, Nordlöf et al. argue that Civic capabilities are distinguished by having an holistic approach to putting knowledge into a context, consistent to the overall aims of the subject of technology. Civic capabilities, being an aim for technological education in school, is therefore not used in the framework for knowledge deriving from school design projects, suggested in this study.

**Technological knowledge emanating in the projects**

Altogether, the three projects impart technological knowledge useful for educating future citizens, as well as preparing students for further studies and working as engineers. However, taken separately, the projects offer different areas of technological knowledge. The Pedometer project covers almost all categories of knowledge within the framework from Nordlöf et al., 2022a, 2022b), while the Bridge project covers Technological skills, parts of Technological scientific knowledge and Engineering capabilities. The Greenhouse project covers almost the same as the Pedometer project, but lacks Socio-ethical technical understanding and Engineering capabilities. Thus, teachers have to be aware that different projects offer quite different opportunities for students to practice their technological knowledge.

The study reveals that the design project is important to technological knowledge in the school subject of technology. Thus the teacher must carefully choose the projects to perform in order to develop a broad technological knowledge. The socio-ethical technical understanding, as well as programming and controlling, are present in the curricula. However, projects involving this content must be carefully planned in order to reach the broad technological knowledge implicated in the curricula. A suggestion for future studies might be to examine more types of common design projects to further develop the framework presented in this study. A special examination of the category Civic capabilities from Nordlöf et al. in relation to other categories is needed.

**A new framework for analyzing design projects**

In Swedish compulsory school, the number of design projects that can be managed during grades 1- 9 are limited due to the regulated hours of teaching. In order to facilitate teachers' evaluation of design projects, I suggest a further development of the framework from Nordlöf et al. The modified framework is associated to design projects including development of physical models. The framework is based on the findings in this study, and thus the category of Civic capabilities is not included. Instead, the new category of Technological research capabilities is included. Table 8 displays the framework, containing five categories of knowledge, what the knowledge is about, and possible knowledge activities within a design project.

***Table 8: A framework for analyzing technological knowledge in school design projects including models***

| Technological knowledge | Knowledge is about | Activities including models |
|---|---|---|
| Technical Skills | - performing a design process – from idea to physical model. | Sketching and drawing<br>Discussing solutions<br>Using trial and error<br>Programming to control functions<br>Building to display solutions<br>Building to display intentions of final product |
| Technological scientific knowledge | - material properties, different construction techniques and functions of sensors and controllers. | Choosing<br>- material for model<br>- material for final product<br>- constructional technique |
| Technological research capabilities | - being able to search, interpret and compare information about technical solutions. | Searching the Internet or real life for solutions<br>Interpreting different solutions<br>Comparing own solution to other solutions |
| Socio-ethical technical understanding | - relating to different aspects of technology. | Adapting to user, society and environment |
| Engineering capabilities | -preparing for further studies and work within engineering. Using technological scientific knowledge to discuss material and constructional solutions. | Running a design project from idea to final product. Might include marketing product. Discussing different solutions. |

## References

Christiaans, H., & Venselaar, K. (2005). Creativity in design engineering and the role of knowledge: Modelling the expert. *International Journal of Technology and Design Education*, *15*(3), 217-236.

Citrohn, B., Stolpe, K., & Svensson, M. (2022). The use of models and modelling in design projects in three different technology classrooms. *International journal of technology and design education*. https://doi.org/10.1007/s10798-022-09730-9

De Vries, M. J. (2005). *Teaching about Technology*. *An introduction to the Philosophy of technology for non-philosophers.* Dordrecht: Springer-Verlag New York Inc.

De Vries, M. J. (2006). Technological knowledge and artifacts: An analytical view. In *Defining technological literacy* (pp. 17-30). Palgrave Macmillan, New York.

De Vries, M. J. (2019). In Dakers, J.R., Hallström, J. & de Vries, M.J. (Eds.). *Reflections on Technology for Educational Practitioners: Philosophers of Technology Inspiring Technology Education*. (p. 25-35). Boston, MA: Brill Publishers.

DiGironimo, N. (2011). What is Technology? Investigating Student Conceptions about the Nature of Technology, *International Journal of Science Education,* 33:10, 1337-1352, DOI:10.1080/09500693.2010.495400

Elo, S., & Kyngäs, H. (2008). The qualitative content analysis process. *Journal of advanced nursing*, *62*(1), 107-115.

Esjeholm, BT. (2015). Design knowledge interplayed with student creativity in D&T projects. *Int J Technol Des Educ* **25**, 227-243. https://doi-org.e.bibl.liu.se/10.1007/s10798-014-9280-1

Hsieh, H. F. & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative health research*, *15*(9), 1277-1288. https://doi.org/10.1177/1049732305276687

Marshall C. & Rossman G. B. (1995). *Designing Qualitative Research*. Sage Publications, London.

Mayring, P. (2004). Qualitative content analysis. *A companion to qualitative research*, *1*(2), 159-176.

Mitcham, C. (1994) *Thinking through technology - The path between engineering and philosophy.* Chicago: University of Chicago Press.

Nordlöf, C., Norström, P., Höst, G., & Hallström, J. (2022a). Towards a three-Part Heuristic Framework for Technology Education. *International Journal of Technology and Design Education*, *32* (3), 1583-1604. https://doi.org/https://doi.org/10.1007/s10798- 021-09664-8

Nordlöf, C., Höst, G. E., & Hallström, J. (2022b). Technology Teachers Talk about Knowledge: from Uncertainty to Technology Education Competence. *Research in Science & Technological Education*, 1-21. https://doi.org/10.1080/02635143.2022.2070150

Norström, P. (2014). How Technology Teachers Understand Technological Knowledge. *International Journal of Technology & Design Education*, *24*(1), 19-38. https://doi.org/10.1007/s10798-013-9243-y

Norström, P. (2015). Knowing how, knowing that, knowing technology. *Philosophy & Technology*, *28*(4), 553-565.

Rauscher, W. (2010). Knowledge-generating activities on which technology education students draw when they design and make artefacts, *African Journal of Research in Mathematics, Science and Technology Education*, 14:1. p. 85-98, https://doi.org/10.1080/10288457.2010.10740675

Skolverket (2021). *Grundskolans läroplan Lgr22, Teknik (Curriculum for compulsory school Lgr22, Technology)* https://www.skolverket.se/download/18.5a061df817791f8257b7c1/1613978696817/Teknik.pdf

Vetenskapsrådet, H. (2017). God forskningssed [Elektronisk resurs]. *Reviderad utgåva*.

Design and Technology Education: An International Journal
28.2

# How to support teachers in becoming teachers as designers of student-centred approaches

**Heillyn Camacho, Aalborg University, Denmark**
**Lone Dirckinck-Holmfeld, Aalborg University, Denmark**
**Geoffrey Tabo, Gulu University, Uganda**

## Abstract
This article presents a design-based research (DBR) methodology to develop a teacher professional development intervention that is aimed at helping teachers become designers of student-centred e-learning activities. The intervention was tested at Gulu University (GU) and Maseno University (MU), and a set of activities and tools, as well as six design principles, were recommended for future interventions. The findings suggest that becoming a designer requires teachers to transform their understanding of their practices and to develop teachers as designers (TasD) mindsets. Further research is needed to conceptualise these mindsets and to map and compare the epistemological traditions of learning, design and teaching practices.

## Keywords
Teachers as designers, learning design, design for learning, design process, designerly ways of thinking, student-centred learning.

## Introduction
At different levels, teachers are increasingly tasked with designing contexts, frameworks, tools, technologies, learning environments (i.e. physical and digital) and learning activities to prepare their students for a constantly changing world. Teachers must cope with twenty-first century learning and teaching dynamics, which demands a paradigm shift from teacher- and curriculum-centred approaches to learner-centred and problem-oriented approaches. The integration of new technologies demands that teachers not only prepare students for meeting the demands of Industry 4.0 regarding competences and knowledge but also incorporate these emerging technologies into their teaching practices to support and foster learning, which requires changing their pedagogical and teaching methods (Miranda et al., 2021).

To address these new educational challenges, teachers need to develop new competences and ways of acting. A promising approach is the incorporation of design in the educational field – particularly emphasising teaching as a design profession (Laurillard, 2012; Warr & Mishra, 2021), with a specific request for teachers to become designers. When there is considerable research scaffolding teachers in their designer roles, for example, focusing on methodologies (Conole, 2014; Conole & Weller, 2008), tools (Yeoman & Carvalho, 2019), design process (Camacho et al., 2018; Young & Perovic, 2018) and patterns (Goodyear, 2005) to guide/support teachers to create designs, we know that some teachers do not perceive themselves as designers and face challenges in applying design principles to their practice (Camacho et al., 2018). To explore and empower teachers to approach educational problems as design challenges, more research is needed. This research should not only focus on providing teachers with methodologies, tools and processes for applying design in their teaching practice but also help shape their role as designers and provide tools to aid in this process.

In this theory-based and empirically tested work, we seek to contribute to design interventions to support teachers in becoming teachers as designers (TasD). We explore two questions: What is required for teachers in higher education to view themselves as designers? How can professional development activities prepare teachers to become TasD? The empirical work in this study was conducted in two universities in the East African region.

This article is structured into six sections. First, we explore how the literature outlines design and education to better develop and conceptualise TasD and review key academic work on TasD. Second, we present our research methodology: design-based research (DBR). Third, we illustrate the design of the intervention (prototype). Fourth, we share the experience of conducting the intervention at Gulu University (GU) in Uganda and Maseno University (MU) in Kenya. Fifth, we propose design principles for future interventions to support university teachers in becoming TasD, followed by the conclusion.

## Teachers as designers (TasD)

Research on teaching and design is broad and covers several disciplinary fields. One of the most comprehensive studies that discusses the different schools of teaching and design is the work of Warr and Mishra (2021). By conducting a literature review, the authors identified ten strands of scholarships that describe TasD and how these strands are conceptually related. The authors employ the term 'strand' to characterise clusters of research that are thematically linked and utilise teaching and design constructs in a comparable manner. Even if Warr and Mishra limited their analysis only to publications with the K12 sector, we find their work relevant to contextualising our understanding of TasD within higher education.

Warr and Mishra identify strands such as *learning design* (Conole, 2013; Goodyear & Dimitriadis, 2013; Laurillard, 2012), where the focus is creating artefacts to scaffold the design process of curriculum learning activities, helping teachers make informed decisions for their designs and making them sharable; *learning by design* (Kolodner et al., 2003), which is considered a design pedagogy (a way of learning); *design thinking* (Meinel & Krohn, 2022), which in recent years has become very popular in the educational context and has been utilised not only as a pedagogy to teach but also as a design epistemology that provides arguments regarding how designers think. Further, we also find *design based research*, *collaborative curriculum design* and *participatory research*. These three strands focus on the collective effort of teachers, researchers and other stakeholders to develop artefacts, learning activities or curriculums. The different strands are connected by the suggestion that design is a key activity of teachers and that teaching can be considered a design profession, with the difference being the approaches of the different researchers for who is doing the design, the role of the teachers, how to support the design process, why framing TasD and the understanding of design (Warr & Mishra, 2021).

This article focusses on the strand of TasD. The specific term of TasD has been more often cited in the field of technology-enhanced learning (TEL) (Kali et al., 2015; Mishra & Koehler, 2006). However, the term has recently expanded to other areas of teaching practices (Henriksen et al., 2020; Kirschner, 2015). In the context of this paper, TasD are practitioners in higher education who, because of their teaching practice, constantly face different type of challenges. University teachers have in general been educated not as teachers but as research practitioners within their fields. Furthermore, TasD are different from professional learning designers; the latter are professionals who assist teachers with applying technology or innovative pedagogies to improve their teaching practice or professionals who design for learning but do not teach (Altena et al., 2019). We do not refer to teachers who help professional designers to design.

In this study, we widen the field of what is designed for beyond TEL. We acknowledge and agree that technology has changed teaching and learning practices, necessitating a design perspective to address this complex and ill-structured challenge. However, teachers need to be designers to address other challenges, such as a) designing a curriculum that fits current and future societal needs, b) generating new learning activities to develop twenty-first-century needs, c) adapting and redesigning innovative pedagogies, d) finding ways to motivate students to stay in school, e) finding ways to communicate and collaborate with various stakeholders, f) devising different approaches to promote students' and teachers' well-being and g) finding ways to becoming learning organisations.

We are aligned with the perspective of Kirschner (2015), who states that TasD must excel in at least three distinct fields. First, TasD must possess deep knowledge about the subjects they teach. Second, they should be well-versed in the art and science of teaching and learning, encompassing an understanding of diverse pedagogical approaches to effectively achieve educational goals. Last, teachers need to grasp the science of design.

This last aspect is the add-on for TasD, because in their role of designers, teachers should be aware of and knowledgeable in the design field: the process, mind-sets, tools and materials. Therefore, TasD are teachers who aim to improve a current situation into a preferred situation by applying rational decision-making (Simon, 1969). TasD are aware that design requires a creative approach to solving problems and demands great competence regarding reflection 'in' and 'on' action (Schon, 1983). They also use designerly ways of thinking (such as creativity, curiosity, openness to different perspectives, collaborative work approaches and willingness to embrace ambiguity) and knowing when to face and approach ill problems (Cross, 2011). TasD convert educational challenges into design challenges and based on the collection of data on students, stakeholders and the context, generate solutions in collaboration with students, colleagues and other stakeholders.

**Related work of supporting teachers in becoming designers**

There is no doubt that teachers engage in design (Garreta-Domingo et al., 2018); however, many teachers do not identify themselves as designers (Henriksen et al., 2020) or are unfamiliar with the practice of design (Bennett et al., 2018). Actually, the design practice for many teachers is tacit; they do not use explicit design knowledge to design their courses and frequently base their design practice on previous experiences (Conole, 2013). Recently, there have been substantial efforts in testing and development of different proposals to support teachers in incorporating design knowledge in their teaching practices.

Some of these proposals are actionable knowledge about design in the form of specific steps that teachers should follow. For example, ABC Learning Design (Young & Perovic, 2018) is a method for systemic and collaborative design and redesign of learning experiences in higher education. This method guides educators to identify the specific learning goals and learning activities in which students should engage during a course module. Other examples are the 7Cs of Learning Design proposed by Conole (2014) and the learning design conceptual framework (Dalziel et al., 2016).

Another proposal that is highly related to the previous proposal is to scaffold the design process through materials, where these materials support the dialogical process, sharing of ideas and making implicit assumptions explicit. These approaches heavily rely on visual thinking. Examples of these approaches are the work of (Yeoman & Carvalho, 2019), who designed a set of cards to facilitate application of the Activity-Centred Analysis and Design method and the D-Thinking Toolkit to apply design thinking in education developed by Tschimmel et al. (2017).

We also find proposals that involve teachers in concrete design processes using specific design methodologies. Research indicates that teachers change their views and meaning of teaching as a design science if they experience a real design process (delimitate the problem, gather and analyse data, co-create with others and use design tools such as brainstorming, diagrams, and visual thinking) using their own practice problems. In other words, rather than offering procedural design approaches, design should be learnt by engaging in design (Gachago et al., 2017). Within this approach, there is the work of Henriksen et al. 2020, who explore how the design thinking framework (Stanford Design Thinking Model) can serve as a framework for teachers to engage and solve real problems in education. Other examples of these kinds of approaches are the work of Boloudakis et al. (2018) and that of Brown et al. (2020). Recent approaches, albeit few, focus on changing the values of teachers (Chai & Koh, 2017) and design mind-sets (Baran & AlZoubi, 2023; Noh & Karim, 2021).

Despite a strong research focus on learning design within educational research in the last decade, further research is needed. To facilitate the process of teachers becoming TasD, we are especially interested in the addition of three elements to the current research. First, we begin by emphasising the importance of explicitly addressing design knowledge. We firmly believe that if we consider teaching as a design profession, then we must treat design knowledge with the seriousness that it deserves. The following questions should receive dedicated and explicit attention when supporting teachers to become TasD: What is design? What truly happens during the design process? How can we approach problems with a designer's ways of thinking? How can we perceive learners through the lens of design?

Second, it is crucial to address design ways of thinking. As mentioned above, many teachers do not consider themselves designers. They have simply not viewed their profession from that perspective, and/or they do not know how designers think and work. To address this issue, an open discussion about their assumptions and beliefs about teaching and design may be fruitful to change their way of thinking.

Last, to carefully design learning spaces to foster the transformation to TasD, our assumption is that physical, online and hybrid spaces must be re-designed to facilitate a designerly way of working (co-creation, visualisation, iteration, flexibility and partnerships).

## Research methodology

Our work is anchored within the context of the Digital Learning Innovation (DLI) project, which is aimed at developing a methodology to implement student-centred e-learning in universities in the East African region (Camacho & Dirckinck-Holmfeld, 2020) The DLI project followed the DBR methodology: 1) understanding and analysis of the practical problem with researchers and practitioners, 2) development of a solution (prototype) informed by theoretical inputs, 3) iterative process of testing and redefining the solution and 4) reflection to produce design principles (Reeves, 2006).

Based on steps 1 and 2 of the DBR methodology, the team formulated the first prototype of the student-centred, e-learning implementation methodology, which is composed of five phases: envisioning, preparing, piloting, scaling up and maturing (Figure 1). The description of the methodology and the tools can be accessed at https://shorturl.at/fxTYZ


***Figure 1: Student-Centred e-Learning Implementation Methodology***

The methodology proposes specific tools for implementing each phase; therefore, a micro-DBR process was conducted to develop each of the tools proposed for each phase.

In this work we present only the micro-DBR process to develop the Learning Designer Workshop (LDW), which is the first tool in the preparing phase (figure 1). Note that the project did not initially have the concept of TasD, so working with TasD evolved through the DBR process.

To generate the first LDW prototype, the project group ran some design workshops and reviewed the literature to inform it (Altena et al., 2019; Bower & Vlachopoulos, 2018; Camacho et al., 2018; Conole & Weller, 2008; Conole & Wills, 2013; Dalziel et al., 2016; Frick et al., 2013; Gauntlett, 2014; Groeger & Schweitzer, 2020; Henriksen et al., 2017; Kohls, 2019; Laurillard, 2012; Lorenzetti et al., 2016; Tracey & Hutchinson, 2016; Tsoukas, 2009; Young & Perovic, 2018). The first prototype of the LDW considered the following theoretical guidelines: 1) it should support teachers to become familiar with an explicit design process that generates a shareable design; 2) teachers would make conscious and explicit pedagogical choices; 3) the learning space should support productive dialogues, knowledge co-creation, visual thinking, collaboration, creativity and play learning; 4) teachers should be provided new tools from the design thinking field; and 5) teachers should be supported to reflect on their role as designers, with the aim of reshaping their professional identity.

The LDW is aimed at guiding academic staff in designing meaningful student-centred learning experiences for an e-learning or blended learning environment. The workshop lasts 30 hours over the course of four or five days, including an online microlearning course to share content about TasD, design for learning and user-centred design.

The first pilot was conducted at Gulu University (GU) during Aug-Sep 2021. The LDW had 20 participants drawn from the faculties of Business and Development Studies, Education and Humanities, and Science and staff from the Library and directorate of technologies services. Participant composition included nine females and 11 males. Most of the participants were young lecturers with master's degrees, with only two having attained a PhD. However, the teaching experience ranged from four to 20 years at a university. The group was divided into two macro groups, which were further subdivided into two subgroups. The two macro groups engaged in different activities.

The second pilot was conducted at Maseno University (MU) during Oct–Nov 2021. The MU pilot study comprised 12 participants from the Faculty of Education, with a learning designer from the e-Campus. The participants comprise five males and eight females. Two participants had teaching experience ranging from seven to 10 years, while the remaining faculty members had accumulated 15 or more years of teaching experience. Importantly, all participants held a PhD degree. The learning designer also functioned as a local facilitator. The group was divided into two subgroups, were engaged in the same activities.

Data were collected in each of the different activities that were implemented at GU and MU (see Table 1). Furthermore, the project team had design and reflection sessions to obtain the final prototype presented in the following section.

***Table 1: Activities and data collected at GU***

| Activity | Data and format |
|---|---|
| Microlearning online course | Exercises completed by the participants |
| LDW (on-site):<br>Macro group 1: ITC staff and library staff members from computer science were introduced to tools to understand students/users (day 1). They collected data through interviews and observations about their users (days 2 and 3) and completed Personas and Learner Empathy map templates with the collected data (day 4). There was a reflection session at the end of the LDW.<br>Macro group 2: Staff members from the other faculties completed the exercises presented in figure 2 (three full days), with the exception of empathy with students. Instead, they had a short future workshop with students. There was a reflection session at the end of the LDW. | Videos with the presentation, material produced by the teachers and audios from the reflection session |
| Working session to analyse the results of the workshops to continue development of the prototype. This two-hour session was conducted only with the project leaders and local leaders. | Word document with the minutes for the sessions and audios. |

The pilot at MU was organised in a manner similar to the pilot at GU, with the exception that they only engaged in the activities of macro group 2. Another difference between the two pilots was that the activities in MU were performed in a hybrid modality, meaning that the teachers and a local facilitator were in the same physical room at MU and the facilitators from Denmark participated by Zoom. The data were analysed to obtain inputs, and the prototype was relevant to help teachers become TasD and to improve the prototype of the LDW.

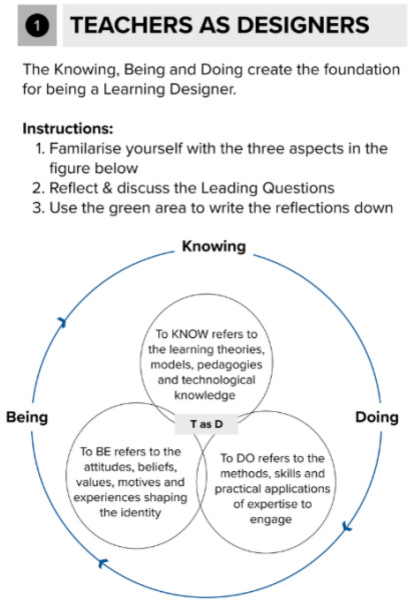
## Prototype of the Learning Designer Workshop (LDW)

The prototype of the LDW is presented visually in Figure 2 (see following pages). The figure represents the improved prototype after the MU pilot. The prototype distinguishes two main activities: introduction to TasD and a process to design courses within the framework of SC-e-learning. The introduction of TasD includes three activities (1–3 in Figure 2), and the design process is composed of five activities (4–8 in Figure 2). Each activity is facilitated through a canvas (the canvases can be downloaded as PDFs here: https://shorturl.at/sHSV4), which was carefully designed to produce a concrete outcome, and materials such as markers, Post-it notes, Legos, flip paper, stickers and a deck of cards. Activities 1–7 should take place in a design thinking environment to facilitate the physical, social and psychological dimensions of the design process.

## 1) TasD Concept

The activity guides the teachers to get to know the theoretical concept of teachers as designers and some examples. Some questions are provided to help the group to reflect, share, and discuss their interpretation of the concept in their everyday practice.

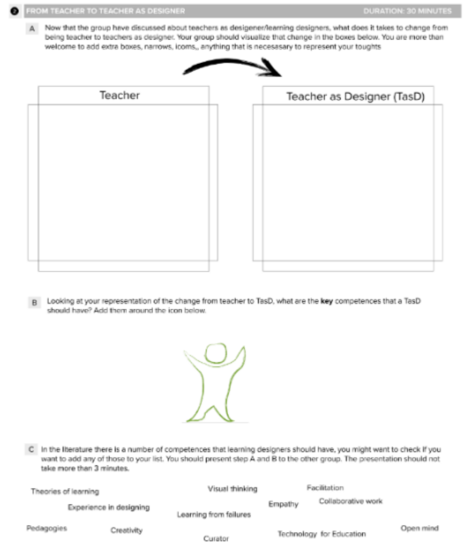
The activity acts as a warming-up exercise and an opportunity to identify point of views, different understandings and relation of the concept with the teaching practice. Post-its are used for individual thinking before moving to group discussions.




## 2) From teacher to TasD

In this activity, teachers go through a process of sense making, co-creation and reflection. First, teachers are asked to draw what it takes to change from being a teacher to becoming a TasD. Afterwards, they are asked to extract concrete attributes of a TasD and draw them or represent them with 3D materials, such as Legos.

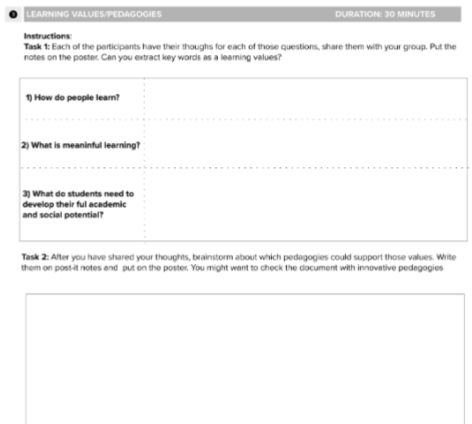
Finally, they are presented with some cards with attributes of designers, and they are asked to discuss whatever the attribute is already in their drawing and if it should be there. Furthermore, they are asked to self-assess if they have those attributes.




## 3) Learning values and pedagogies

In this activity teachers make their learning and teaching assumptions and values explicit. They answer 3 questions: how do people learn? What is meaningful learning and What do students need to develop their full academic and social potential?

After sharing their answer, they work with an affinity diagram to promote dialogue. Then, they are asked to brainstorm about which pedagogies could support those values. The group gets 10 cards with innovative pedagogies and they are guided to discuss how those pedagogies can materialise their learning and teaching values.



### 4) Future Workshop: what are our challenges?

This activity helps the group to identify educational challenges. The Future workshop (FW) is composed of three steps: critique phase, vision phase and realization phase. The group skips the last step. The FW starts with a question related to the challenge at hands and then finishes with an ideal scenario. The result of this activity is the course or problem that the teacher will work with during the design process.


### 5) Empathy: understanding our students

In this activity, teachers learn tools to get to know their students better: Learner Personas, Learner Empathy Map, and Learning Experience Map. Participants gather data by interviews or/and observation.


### 6) Define: context and learning goals

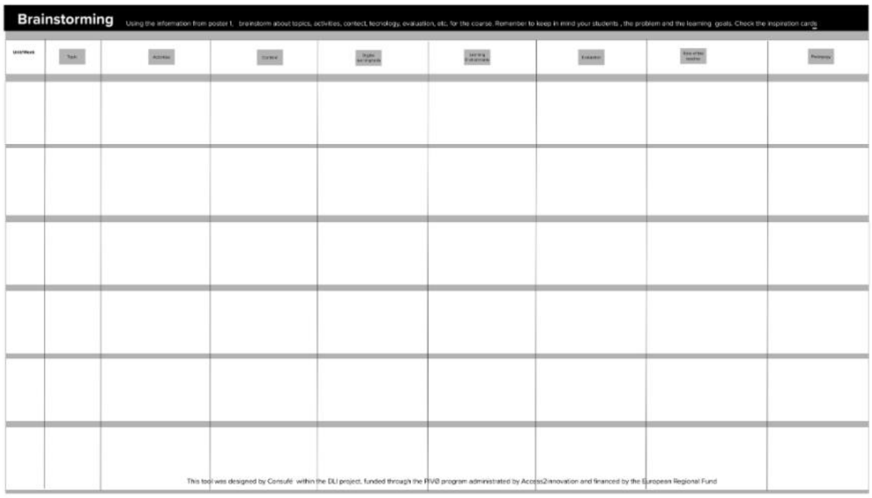
Teachers visually represent all the organizational aspects that will impact the design of the course, such as exams rules, durations, location of the course in the curriculum, possible external collaborators and overall pedagogy for the course, among other aspects.

The activity finishes with the definition of the learning goals.

**7) Ideate: Collective knowledge**

Participants are guided to gather ideas for the relevant aspects for the course design: topics to cover, learning activities, content, learning environment, digital technologies, role of the teachers and students, assessment. They are encouraged to individually brainstorm to generate ideas for the different aspects and then create a kind of student learning journey together.

Teachers are supported with a deck of inspirational cards about technologies, SC learning activities and assessment activities. They conclude with a course blueprint in a Word format.




**8) Create: from prototype to digital platforms**

In this activity is ore production where the course is implemented on the institutional Learning management system, including the production of material and learning activities.

***Figure 2: Prototype of the Learning Designer Workshop***

## Experience of teachers working with the prototype

In this section we present the third step of the DBR methodology: the iterative process of testing and redefining the prototype of the LDW. We observed from the data that different elements interwind to create an experience that was significant and meaningful for the participants; however, we attempted to reflect separately on three main aspects – materials, the process and outcomes, which allowed us to improve the prototype and generate more elaborate design principles for supporting teachers to become designers. Before reading the next sections, we recommend having a look at figure 3 to get a glimpse of how the teachers worked in GU and MU.

### Material suitability – Tools and space

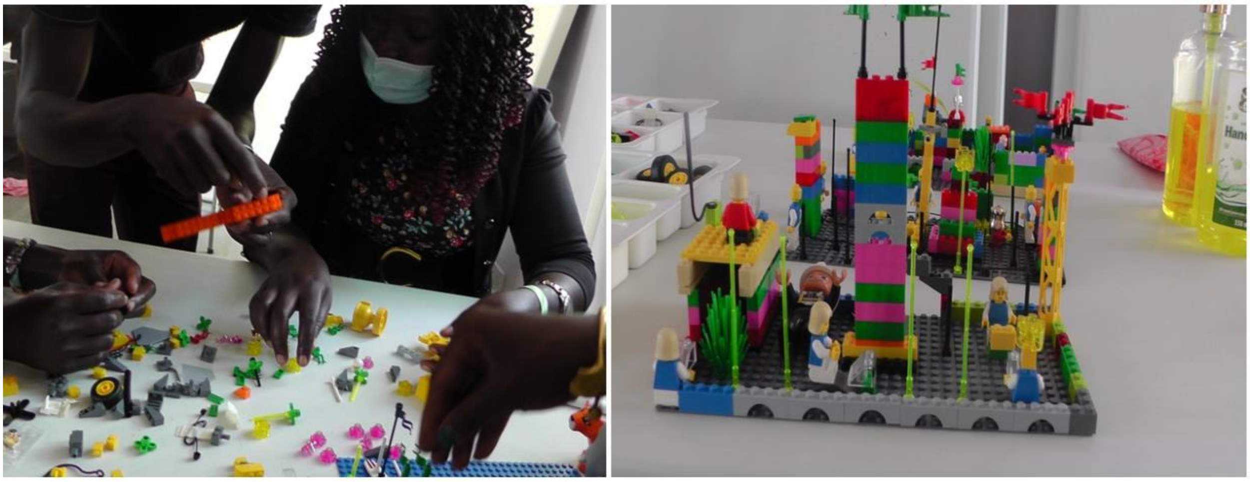
Regarding materials, we refer to the canvases (tools) used in the different activities (1–7 in Figure 2), the materials to work with the canvases and the learning space where the activities took place. The canvases are not just a visual representation in digital or paper format; they represent the embedded actions that the participants were guided to do.

The canvases and the specific materials to work on them promote new ways of interacting, reflecting, thinking (individually and collectively), co-creating, making decisions and learning. As one person from MU stated:

> *The tools were good because they allowed us to give honest opinions. The tools made us to do some critical thinking. The tools enable us to come up with our real challenges. At one point we were looking at is it really competency? So then we need capacity building. Is it infrastructure? Is it our attitude? The tools unconsciously enable you to respond in an honest manner. (V-MU-RS-F)*

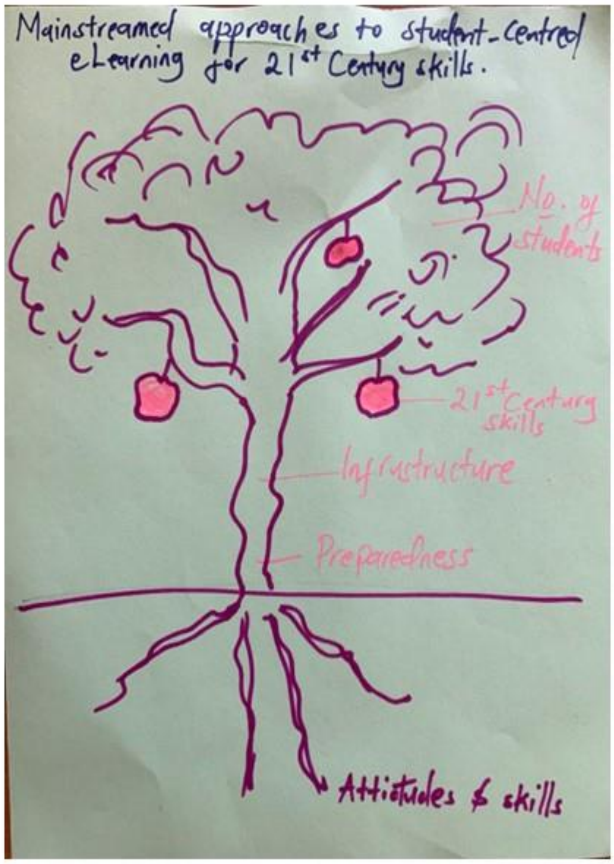
The Future Workshop (FW, canvas 4) supports a problem-solving mindset, which is a key element in design thinking. The tool scaffolded the groups to collectively identify the key issues that they were facing and to define and select the significant issues to work on. The FW provided a framework to collect inputs from each group member and form a common understanding, moving from individual opinions and experiences to collective reflections and decisions. The tool was totally new for the group in MU, and as one participant (teacher) indicated, it 'throws them out of balance' but in a positive way because it broke their traditional way of thinking and idea of participating roles. The FW provided a dialogical space where all voices contributed – producing two metaphors for the significant problems, as they wanted to focus on including their vision for the future. The developed problems were how to design for large classes based on SC approaches, such as problem based learning (PBL), and how to train teachers on learning design.

The tools adapted from the design thinking tools, such as learner personas and empathy maps (EMs), were meaningful, useful and revelatory for the participants. Those tools are concrete ways to understand students and empathise with the needs, desires, challenges, frustrations and strengths of the learners. These tools helped to create genuine SC learning and start the process of thinking about how to deal with the diversity of talents and needs in the classroom that need to be approached with different strategies.

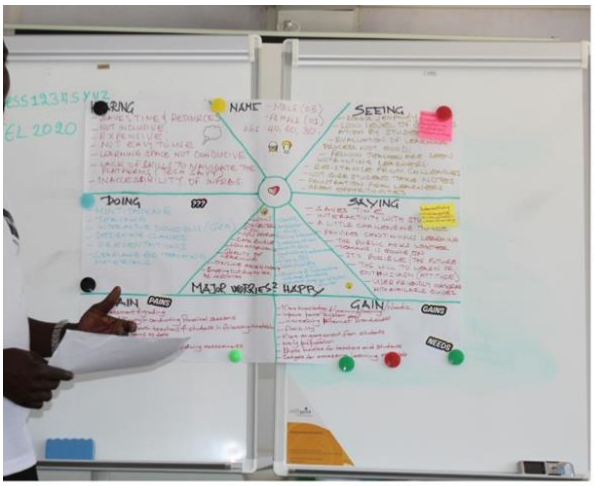


Work from Gulu University – working with Legos to construct their meaning of teachers as designers

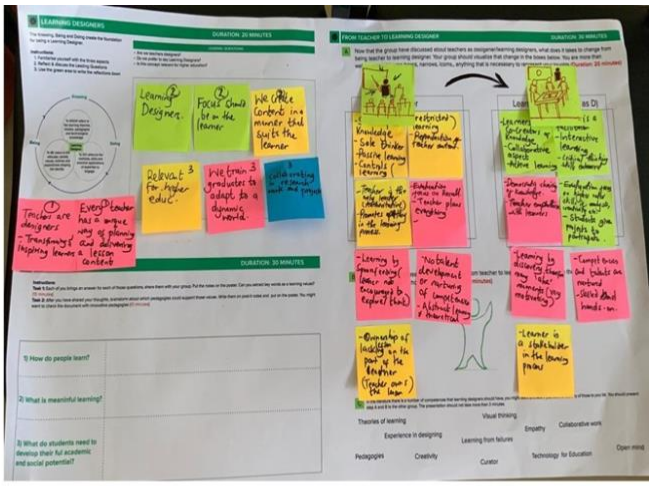
View of the learning space in Gulu University




Work from Maseno University – Working with methaphorical thinking during a future workshop



Work from Gulu University – Learner Empathy Map



Work from Maseno University – Working with the step 1, 2 and 3 of Learning designer workshop

***Figure 3: Glimpse of work carried out in GU and MU***

Furthermore, collecting data from students with these tools and presenting visually enabled teachers to get insights into the students' behaviour. For example, when presenting the results of the EMs, one group indicated that the class dropout rate was high during the COVID-19 pandemic, highlighting that a lecturer could start a class with 100 students and finish with only one-third (V-GU-EM-P). But the inputs from a group of students, showed that students mentioned that internet access was quite expensive and that sometimes they had access for only two hours (the duration of a lecture), but lectures sometimes did not start on time, meaning that they did not have enough internet access to finish the lecture (M-GU-FW). Such behaviour (starting lectures late) that was normal in face-to-face classes did not cause major problems for the students. In the new setting (online teaching), it became a problem, and teachers could see and understand it well from the EMs. The EMs also revealed the students' frustrations with the assessment and grading on the digital platform used by the university during the pandemic. The teachers wondered if these frustrations were derived from the students' lack of training in the use of the platform (V1-UCDW-EM).

The suitability of the tools is closely related to the use of materials provided to work with the tools and in the learning environment. The unusual approach of using tangible materials (Legos, prototyping materials, cards, markers, stickers, etc.) to design a course was perceived as a valuable way to support thinking, knowledge sharing and co-creation and had an impact on how to perceive and understand design. One person indicated:

> *We were able to collaborate and come up with one finished diagram that represents our thoughts and expresses our ideas, and it was quite critical because we had to reason, it had to make sense, be logical, you know, we discovered and expressed ourselves in all these forces without even thinking consciously about. (…) The visual aspect is very important; it relates to a lot of your senses, what you see, what you hear, how you react. The tools were more engaging by having the visual element. If we are talking about collaboration, dialogue and communication, it is a plus to have those kinds of visual tools. (V-MU-RS-F)*

Visual thinking tools were applied in all workshops, and gradually, a rich data, information and knowledge space was created. Each group created 'corners' with its canvas, which allowed constant validation, referencing and checking of information that enabled a continuous knowledge creation process. There were several instances of participants making statements such as 'Do you remember that Monday we were working with the FW and that we came up with this metaphor?' They were referring to materials hanging on the walls.

The movable small whiteboards were also a game-changing factor in the interaction of the groups, as they a) were used to materialising and systematising the ongoing discussion and b) could move the whiteboards easily to different working spaces within the room. This underlines that all tools affect the design process, denoting the importance of being intentional when equipping design-learning spaces. In general, the participants appropriated the space, which then facilitated the different stages of the design process. This setting was perceived as a valuable in a context that does not typically provide many opportunities for such types of interactions.

Regarding improvements to the prototype, canvas 7 needs to be redesigned, because even though it includes all the elements that a course designer needs to consider, it is difficult for the teachers to take all the elements at once. Furthermore, we can identify a missing tool: the technological tools to support the design process – that is, advanced technologies that can quickly and easily process and visualise data, such as AI, learning analytics, machine learning, and big data.

**Relevance of the process**

At the beginning, the teachers did not see themselves as designers. We observed a change as the teachers participated in the flow of the design process as a co-creation experience. They engaged in different discussions and reflections and slowly progressed in the production of tangible and valuable outcomes of designing an e-learning course within the frame of an SC approach. As such, the prototype was successful in promoting and encouraging reflection in and on action (Schon, 1983). Participants reported to have been challenged by the different activities to reflect and explicitly state their learning and teaching theories, problems and assumptions. The process motivated them to make the implicit explicit, and by doing so, they negotiated meaning, came to a mutual understanding and sometimes made adjustments or changes to their meanings or ways of thinking.

The participants highly appreciated working with their own real challenges and getting things done:

> *In these sessions we had WORKSHOPS, which means you are exposed and you implement, you do your work. [We] evaluate, scientifically, what the impact of what we have learnt to our learners is [and] the impact on our staff. Where are we now, and what is the impact of this? (V-MU-RS-F)*
>
> *Normally, when we do training, the learning goes with the trainers; for us, it remains here. You came at the right time. (V2-UCDW-EM)*

In the test at GU, we assembled teachers, ICT staff and library staff to work together, which was valuable for the three different groups. The groups were able to better understand each other's challenges, daily tasks and perspectives, being the most significant contribution of getting to work together to find solutions. The groups experienced the benefits of interdisciplinary collaborative work. One of the teachers reflected on the experience of working in a multidisciplinary group:

> *If you see this combination, the work from different entities there, [and] if we work in collaboration with the library, the ICT, and this department, we are able to improve on the quality of learning and teaching, and [as] stated from the start, it was student-centred learning. So, as the three teams can come together and see how we can design or improve on these platforms that we have (…), then certainly, this gentleman [referring to the person from the ICT department] is well blessed. Thank you for being around us, because we can voice out. (V2-UCDW-EM)*

Important feedback on the prototype is to find a balance between the process and the product. The design process was oriented towards producing a course designed with the SC-e-learning approach, which is innovative in several ways. However, this approach poses the risk of leading teachers back to the traditional way of thinking when asked to design a course. In our data we found examples of this challenge. During our GU pilot, we guided the teachers in selecting a course to be redesigned within the SC framework. However, we did not explicitly ask them to identify problems with the course itself. Here, we observed that teachers went back to the model of planning a 'content-based' course and did not focus on competences and student's needs and desires, even though they were aware of this approach. When brainstorming about learning activities, they could come mainly with the activities that they already had in the course. We believe that we unintentionally moved the teachers to a zone where they knew very well what to do, and they started ‘doing business as usual’. The intervention of the facilitators and the use of inspirational cards helped teachers move out of this ‘zone’.

At MU, we modified the process based on what we had learnt from GU, but here also, the teachers were somewhat stuck in the course metaphor. Even though they came up with different real problems that they were facing and chose two problems as design challenges, we altered the problem-solving process because the canvas guided to a preestablished solution: ‘a course’. We do not know if the solution to their problems could have been something different than a course. From the perspective of scaffolding to help teachers experience the design process, the fact that our steps lead to designing a course might have affected the freedom of teachers to explore and follow unexpected solutions.

We have modified our prototype, clarifying that teachers should identify problems for a specific teaching and learning activity (often a course) and then start the design process from there. However, as the aim is to support teachers to become designers, they should not be working to design a course in their first training but focus on identifying an educational challenge and finding a solution, going beyond the course metaphor. This finding is particularly important – as it demonstrates the need to be deliberate and explicit in the definition of the concepts used in the methodology, which should also be mirrored in the scaffolding materials (especially canvas 7, which needs to be redesigned).

**Outcomes**

The prototype achieved the goals of designing courses within the SC framework, as each of the groups finished with a course blueprint and adopted/adapted new SC activities and technologies. Furthermore, the groups implemented their blueprints in a learning management system. We can state that the prototype also achieved the aim of moving teachers closer to being designers, as they became aware of their design practice and started engaging in designerly ways of thinking.

Canvases 1 and 2 allowed teachers to engage in deep reflections and discussions about their roles as designers. At the beginning the participants did not consider themselves designers and instead saw themselves as professors/teachers. Even though they could recognise that they do design, they visualised a designer in the light of an artist, architect, fashion designer and the like. However, as they went deeper into their teaching practice, they realised that they also do design in this context.

When arguing to call teachers, designers, some of the groups concluded, ‘Every teacher has a unique way of planning and delivering lesson content’, ‘we train graduates to adapt to a dynamic world’ and ‘we collaborate in research works and projects’. When differentiating teachers from those who act as designers, the main differences were that the latter ‘empathise with the needs of the learners’ and ‘focus on formative learning’, ‘learning happens in two ways’ (meaning that teachers also learn) and TasD ‘are inspirational, creative, innovative and interact with the learner’ (M-MU-C1&2).

We consider that promoting design-thinking mindsets might have a strong influence on the way teachers think and do things, which might help to enrich their practice. Design tools and the design process are important, but they materialise from a particular way of thinking. Then by strengthening ways of thinking, in this case as designers, the focus transitions from tools and procedures to values and ways of working. In other words, it is not necessarily learning about and how to use, for example, personas, but learning the value and relevance of being SC and empathic. It is not about using Legos bricks but understanding that we think and communicate differently through materials, that expressing untangled concepts (such as feelings) might be easier by using visual thinking and that a little piece of Lego might trigger a totally different way to understand a situation or generate an idea.

## Design principles to support teachers in becoming designers

In this section we present five design principles to be considered when working with interventions for TasD, which respond our second research question: how to facilitate professional development activities to prepare teachers to become designers?

*Principle 1: Create learning experiences for teachers by introducing TasD to concrete design models and tools.*

Our field test supports the use of concrete design models to help teachers manage the messiness of the design process and create a structure to understand design processes, as the literature presents several design processes. Having concrete tools (such as the canvases) for each of the design steps provides actionable knowledge for teachers. However, as designers, we also need to be critical of the conceptualisations, which are materialised in the supporting tools, for example reflect on the use of the metaphor of 'courses'. This principle of providing concrete tools aligns with the works of (Brown et al., 2020; Henriksen et al., 2020; Yeoman & Carvalho, 2019).

*Principle 2: Facilitate genuine learning experiences through participation in a creative and collaborative problem-oriented process based on teachers' own realities.*

This principle is aligned with the work of Henriksen, Gretter, and Richardson (2020), who indicate that teachers might change their view and meaning of teaching as design science if they experience a real design process using their own practice problems.

*Principle 3: Explicitly emphasise designerly ways of thinking.*

It was evident from our pilots that the participating teachers did not consider themselves designers. However, when they were first introduced to the concept and then participated in the different activities, the demonstration of attributes such as empathy for students, metaphorical thinking, visual thinking, problem roots, thinking with Legos, co-creation and critical reflection, they started to understand the relevance. Processes and tools of design thinking are grounded in a set of mindsets which originate from a culture of a specific way of thinking (Schweitzer et al., 2016).

Most of these ways of thinking are closely related to the practice that teachers as professionals already perform; however, we argue that design thinking mindsets should more explicitly become part of teachers' values.

*Principle 4: Provide physical, social and temporary learning spaces that allow for co-creation, embodiment and sensemaking with others.*

The influence of space on the learning process (Bøjer, 2021), knowledge creation (Nonaka & Takeuchi, 1995) and innovation and creativity (Kohls, 2019) is well documented. Physical space affects how people think and behave and how and with whom they interact; therefore, when we engage teachers in a set of activities to foster the transformation to designers, the space (physical and digital) should be designed to facilitate the kind of interactions and knowledge creation that we intend to support.

*Principle 5: The purposive use of materiality in design is an important element in bringing teachers closer to being designers.*

Thinking through materials facilitates conversations, creates knowledge, fosters participation, facilitate to convert tacit knowledge into explicit and enables the formation of innovative spaces, among other purposes. Many teachers are used to oral communication; therefore, working with Legos, Post-it notes, sketching tools, card sorting materials supports the externalisation of thoughts and fosters creativity, communication, understanding and co-creation. Thinking through materials supports the immersion of teachers into the practice of designers and enhances the experience.

## Conclusions

In this work we used DBR to create a teacher professional development intervention that helps teachers to become designers and to design SC-e-learning activities. The proposal includes specific tools, a concrete set of activities, a set of ways of thinking to be promoted and a set of design principles to be considered in future interventions.

The intervention was tested in two different settings in East African universities, demonstrating that the method has the necessary qualities to achieve the expected goals. The intervention is the first step in the journey of training teachers to become designers. The best way to develop teacher as designer skills is by performing the role as a part of everyday practice – in other words, by approaching real complex problems and addressing them with a design mindset and design approach. While we observed that teachers related quickly with the new design practice and recognised that they as teachers do design in different ways, the intervention also documented that the development of design skills and mindsets demands time, resources and a willingness to change on the part of both teachers and institutions (Rylander Eklund et al., 2022).

Most of the teachers were immersed in a social practice that has some design traits, but it is not practiced as a design craft. Therefore, becoming TasD demands a transformation in the way that teachers understand their own practices in relation to the design practice (practice and the cultural context in which the design thinking methods and mindsets emerge) to get the full potential of applying a design perspective to current teaching practices.

In this respect we note the need for further research to map and compare the epistemological traditions of learning, design and teaching practices to obtain a better understanding of TasD. There are many shared values of constructivist, experiential and situated learning theories and design practice. These shared values are applied by teachers when teaching but not when designing for learning. Explicit examples of certain learning theories that can be reformulated in design for learning might provide a meaningful learning experience for teachers, as it might help them connect previous knowledge to a new practice (design).

We consider that our prototype provides good scaffolding for the teachers to become designers; however, we should be careful not to fall into 'lobotomy', a metaphor used by Verganti (2017) to refer to a practice in management of making design thinking so digestible that it eradicates the creative power of designers. We need to find a balance to keep ambiguity, emotions, intuition, confusedness, play with images, metaphors, storytelling, the prototype and sensemaking of the design practice while still helping teachers to get relevant outcomes for their practice.

Finally, we recommend further research on TasD mindsets, supporting teachers to incorporate design into their teaching practice. Some sound studies have defined design thinker mindsets (Baran & AlZoubi, 2023; Brown et al., 2020; Vignoli et al., 2023), but a well-elaborated mindset for TasD has not been elaborated. We consider that the Scandinavian literature on IT didactic design (Levinsen & Sørensen, 2019) may contribute to developing a framework for a TasD mindset.

## Acknowledgements

We are particularly thankful to the Centre of Excellence in ICT and Learning established through the Building Stronger Universities programme, which is funded by Danida; the Digital Learning Initiative, funded by Access2innovation; PIVØ; Consufé; CanopyLAB; Gulu University; and Maseno University staff and students for actively participating in this research project and the administration for granting the much-needed permissions to conduct this project.

## References

Altena, S., Hinze, R., Poulsen, M., Parrish, S., & Dominique, R. (2019). *Many hats one heart": A scoping review on the professional identity of learning designers*. 359–364.

Baran, E., & AlZoubi, D. (2023). Design thinking in teacher education: Morphing preservice teachers' mindsets and conceptualizations. *Journal of Research on Technology in Education*, 1–19. https://doi.org/10.1080/15391523.2023.2170932

Bennett, S., Lockyer, L., & Agostinho, S. (2018). Towards sustainable technology-enhanced innovation in higher education: Advancing learning design by understanding and supporting teacher design practice. *British Journal of Educational Technology*, *49*(6), 1014–1026. https://doi.org/doi:10.1111/bjet.12683

Bøjer, B. (2021). Creating a Space for Innovative Learning: The Importance of Engaging the Users in the Design Process. In W. Imms & T. Kvan (Eds.), *Teacher Transition into Innovative Learning Environments: A Global Perspective* (pp. 33–46). Springer Nature Singapore. https://doi.org/10.1007/978-981-15-7497-9_4

Boloudakis, M., Retalis, S., & Psaromiligkos, Y. (2018). Training Novice teachers to design moodle-based units of learning using a CADMOS-enabled learning design sprint. *British Journal of Educational Technology*, *49*(6), 1059–1076. https://doi.org/10.1111/bjet.12678

Bower, M., & Vlachopoulos, P. (2018). A critical analysis of technology-enhanced learning design frameworks. *British Journal of Educational Technology*, *49*(6), 981–997. https://doi.org/10.1111/bjet.12668

Brown, B., Friesen, S., Beck, J., & Roberts, V. (2020). Supporting New Teachers as Designers of Learning. *Education Sciences*, *10*(8), 1–14. https://doi.org/10.3390/educsci10080207

Camacho, H., & Dirckinck-Holmfeld, L. (2020). *Student-Centered e-learning Implementation A participatory Approach* (DLI Project, p. 16) [Project Report]. Access to Innovation. Student-Centered e-learning Implementation A participatory Approach

Camacho, H., Skov, M., Jonasen, T. S., & Ryberg, T. (2018). Pathway to support the adoption of PBL in open data education. *Design and Technology Education: An International Journal*, *23*(2), 1–19.

Chai, C. S., & Koh, J. H. L. (2017). Changing teachers' TPACK and design beliefs through the Scaffolded TPACK Lesson Design Model (STLDM). *Learning: Research and Practice*, *3*(2), 114–129. https://doi.org/10.1080/23735082.2017.1360506

Conole, G. (2013). *Designing for Learning in an Open World*. New York, NY : Springer New York.

Conole, G. (2014). The 7Cs of Learning Design – a new approach to rethinking design practice. In S. Bayne, C. Jones, M. de Laat, T. Ryberg, & C. Sinclair (Eds.), *Proceedings of the 9th International Conference on Networked Learning 2014* (pp. 502–509).

Conole, G., & Weller, M. (2008). Using Learning Design as a Framework for Supporting the Design and Reuse of OER. *Journal of Interactive Media in Education*, *1*(5), 1–13. https://doi.org/10.5334/2008-5

Conole, G., & Wills, S. (2013). Representing Learning Designs—Making Design Explicit and Shareable. *Educational Media International*, *50*(1), 24–38.

Cross, N. (2011). *Design Thinking: Understanding How Designers Think and Work*. Berg.

Dalziel, J., Conole, G., Wills, S., Walker, S., Bennett, S., Dobozy, E., Cameron, L., Badilescu-Buga, E., & Bower, M. (2016). The Larnaca Declaration on Learning Design. *Journal of Interactive Media in Education*, *1*(7), 1–24. http://dx.doi.org/10.5334/jime.407

Frick, E., Tardini, S., & Cantoni, L. (2013). *White Paper on LEGO®SERIOUS PLAY® A state of the art of its applications in Europe* (p. 29) [Project Report]. S-Play Project.

Gachago, D., Morkel, J., Hitge, L., van Zyl, I., & Ivala, E. (2017). Developing eLearning champions: A design thinking approach. *International Journal of Educational Technology in Higher Education*, *14*(1), 30. https://doi.org/10.1186/s41239-017-0068-8

Garreta-Domingo, M., Hernández-Leo, D., & Sloep, P. B. (2018). Education, Technology and Design: A Much Needed Interdisciplinary Collaboration. In E. Kapros & M. Koutsombogera (Eds.), *Designing for the User Experience in Learning Systems* (pp. 17–39). Springer International Publishing. https://doi.org/10.1007/978-3-319-94794-5_2

Gauntlett, D. (2014). The LEGO System as a tool for thinking, creativity, and changing the world. In M. Wolf (Ed.), *LEGO Studies: Examining the Building Blocks of a Transmedial Phenomenon* (1st ed., pp. 189–205). Routledge. https://doi-org.zorac.aub.aau.dk/10.4324/9781315858012

Goodyear, P. (2005). Educational design and networked learning: Patterns, pattern languages and design practice. *Australasian Journal of Educational Technology*, *21*(1). https://doi.org/10.14742/ajet.1344

Goodyear, P., & Dimitriadis, Y. (2013). In medias res: Reframing design for learning. *Research in Learning Technology*, *21*, 1–13. https://doi.org/10.3402/rlt.v21i0.19909

Groeger, L., & Schweitzer, J. (2020). Developing a Design Thinking Mindset: Encouraging Designerly Ways in Postgraduate Business Education. In G. Melles (Ed.), *Design Thinking in Higher Education: Interdisciplinary Encounters* (pp. 41–72). Springer Singapore. https://doi.org/10.1007/978-981-15-5780-4_3

Henriksen, D., Gretter, S., & Richardson, C. (2020). Design thinking and the practicing teacher: Addressing problems of practice in teacher education. *Teaching Education*, *31*(2), 209–229. https://doi.org/10.1080/10476210.2018.1531841

Henriksen, D., Richardson, C., & Mehta, R. (2017). Design thinking: A creative approach to educational problems of practice. *Thinking Skills and Creativity*, *26*, 140–153. https://doi.org/10.1016/j.tsc.2017.10.001
Kali, Y., McKenney, S., & Sagy, O. (2015). Teachers as designers of technology enhanced learning. *Instructional Science*, *43*(2), 173–179. https://doi.org/10.1007/s11251-014-9343-4
Kirschner, P. A. (2015). Do we need teachers as designers of technology enhanced learning? *Instructional Science*, *43*(2), 309–322. https://doi.org/10.1007/s11251-015-9346-9
Kohls, C. (2019). Hybrid Learning Spaces for Design Thinking. *Open Education Studies*, *1*(1), 228–244. https://doi.org/10.1515/edu-2019-0017
Kolodner, J. L., Camp, P. J., Crismond, D., Fasse, B., Gray, J., Holbrook, J., Puntambekar, S., & Ryan, M. (2003). Problem-Based Learning Meets Case-Based Reasoning in the Middle-School Science Classroom: Putting Learning by Design(tm) Into Practice. *Journal of the Learning Sciences*, *12*(4), 495–547. https://doi.org/10.1207/S15327809JLS1204_2
Laurillard, D. (2012). *Teaching as a Design Science—Building Pedagogical Patterns for Learning and Technology*. Routledge.
Levinsen, K., & Sørensen, B. (2019). Teachers' Designs for Learning Practices when Designing for Students as Learning Designers. *Designs for Learning*, *11*(1), 30–39. https://doi.org/10.16993/dfl.111
Lorenzetti, L., Azulai, A., & Walsh, C. (2016). Addressing Power in Conversation: Enhancing the Transformative Learning Capacities of the World Cafe. *Journal of Transformative Education*, *14*(3), 200–219. https://doi.org/10.1177/1541344616634889
Meinel, C., & Krohn, T. (Eds.). (2022). *Design Thinking in Education—Innovation can be learned*. Springer Cham. https://doi.org/10.1007/978-3-030-89113-8
Miranda, J., Navarrete, C., Noguez, J., Molina-Espinosa, J.-M., Ramírez-Montoya, M.-S., Navarro-Tuch, S. A., Bustamante-Bello, M.-R., Rosas-Fernández, J.-B., & Molina, A. (2021). The core components of education 4.0 in higher education: Three case studies in engineering education. *Computers & Electrical Engineering*, *93*, 107278. https://doi.org/10.1016/j.compeleceng.2021.107278
Mishra, P., & Koehler, M. J. (2006). Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge. *Teachers College Record*, *108*(6), 1017–1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x
Noh, S. C., & Karim, A. M. (2021). Design thinking mindset to enhance education 4.0 competitiveness in Malaysia. *International Journal of Evaluation and Research in Education*, *10*(2), 494–501. https://doi.org/DOI: 10.11591/ijere.v10i2.20988
Nonaka, I., & Takeuchi, H. (1995). *The knowledge-creating company: How Japanese companies create the dynamics of innovation*. Oxford University Press.
Reeves, T. (2006). Design research from a technology perspective. In J. Van den Akker, K. Gravemeijer, S. Mckenney, & N. Nieveen (Eds.), *Educational Design Research* (1st Edition, pp. 52–66). Routledge. https://doi.org/10.4324/9780203088364
Rylander Eklund, A., Navarro Aguiar, U., & Amacker, A. (2022). Design thinking as sensemaking: Developing a pragmatist theory of practice to (re)introduce sensibility. *Journal of Product Innovation Management*, *39*(1), 24–43. https://doi.org/10.1111/jpim.12604
Schon, D. (1983). *The Reflective Parctitioner: How Professionals Think in Action*. Basic.
Schweitzer, J., Groeger, L., & Sobel, L. (2016). The Design Thinking Mindset: An Assessment of What We Know and What We See in Practice. *Journal of Design, Business & Society*, *2*(1), 71–94. https://doi.org/10.1386/dbs.2.1.71_1

Simon, H. A. (1969). *The sciences of the artificial*. MIT press.
Tracey, M. W., & Hutchinson, A. (2016). Uncertainty, reflection, and designer identity development. *Design Studies*, *42*, 86–109. https://doi.org/10.1016/j.destud.2015.10.004
Tschimmel, K., Loyens, D., Soares, J., Oraviita, T., & Santos, J. (2017). *D-Think Toolkit. Design Thinking Applied to Education andTraining.* Erasmus+. https://www.researchgate.net/publication/320197120_D-Think_Toolkit_Design_Thinking_Applied_to_Education_and_Training/citations
Tsoukas, H. (2009). A Dialogical Approach to the Creation of New Knowledge in Organizations. *Organization Science*, *20*(6), 941–957. https://doi.org/doi.org/10.1287/orsc.1090.0435
Verganti, R. (2017). Design Thinkers Think Like Managers. *She Ji: The Journal of Design, Economics, and Innovation*, *3*(2), 100–102. https://doi.org/10.1016/j.sheji.2017.10.006
Vignoli, M., Dosi, C., & Balboni, B. (2023). Design thinking mindset: Scale development and validation. *Studies in Higher Education*, *48*(6), 926–940. https://doi.org/10.1080/03075079.2023.2172566
Warr, M., & Mishra, P. (2021). Integrating the discourse on teachers and design: An analysis of ten years of scholarship. *Teaching and Teacher Education*, *99*, 103274. https://doi.org/10.1016/j.tate.2020.103274
Yeoman, P., & Carvalho, L. (2019). Moving between material and conceptual structure: Developing a card-based method to support design for learning. *Design Studies*, *64*, 64–89. https://doi.org/10.1016/j.destud.2019.05.003
Young, C., & Perovic, N. (2018). *Introduction to the ABC LD workshop* (Project Report 1; HEFCE Action for Curriculum Excellence Project 2016-18, p. 17). UCL.

Design and Technology Education: An International Journal

28.2

# Educating designers with 3D printers: a postphenomenological perspective on maker and design pedagogy

**Nenad Pavel, Oslo Metropolitan University, Norway**

## Abstract
Learning in makerspaces is free from curriculum and evaluation and is believed to yield practical, self-driven and solution-oriented learners. This study explores how makerspace pedagogy can be emulated in formal higher education settings to support this kind of learning. Action research was used to cultivate and review this pedagogical approach in three repeated design studio courses using three-dimensional (3D) printing lab. The maker pedagogy was to support self-driven learning emerging in relationship between learners, their social environment and technology media. Maker and design pedagogy has been further theoretically developed using postphenomenology as a process of learners' adoption of 3D printers in own design practice, learners' adaptation to the affordances of the 3D printers, and attainment of learners' own goals in social contexts using 3D printing technology. Finally, the study indicates how shifting from constructivist to postphenomenological theoretical concepts can give new insights and strengthen sustainable pedagogical practices. Limitations and opportunities for maker pedagogy in formal education are addressed with these new insights.

## Keywords
Technological Media, Design Pedagogy, Maker Pedagogy, Postphenomenology, 3D print.

## Introduction: emulating makerspace qualities in formal education
The emergence of alternative informal education, such as makerspaces, has drawn the attention of educators. Some formal study programs in the field of science, technology, engineering, and mathematics have seized the opportunity to borrow some makerspace learning qualities. As a result, makerspace workshops have been established at universities with the promise to encourage an experimental and hands-on approach to learning. The existing literature (Ford & Minshall 2019) has shown many of these attempts to integrate makerspace pedagogy to increase student engagement, motivation, curriculum implementation, and learning efficiency. Benefits have also been noted to include increased student creativity, especially the ability to 'define problems' and 'design solutions' as core engineering practices (Quinn & Bell 2013). Accordingly, this kind of thinking is important for learners' 'individual agency and can foster learners' autonomy' (45).

However, researchers such as Godhe, et.al., (2019) have scrutinized these claims due to the issues arising from attempts to emulate makerspace learning approaches in formal education. They question the promise of maker-based education and called for research on not only successful cases of the implementation of maker technology and pedagogy in formal education but also those producing average and failed results. Their paper addresses issues and proposes both the reconfiguration of maker technologies and calls for new ideas for 'alternative conceptual pedagogical frameworks that move beyond the narrow concerns of maker education' (11) that can fit formal education in a more effective way. Of the issues raised in this paper, I would like to outline and elaborate on two.

The first issue involves curricula or learning content. Maker movements rest on the free endeavors of their participants, who learn through play in a social setting and freely explore what interests them (Martin 2015). Therefore, learning through maker technologies, according to some theoreticians (Martin 2015; Bevan 2017), should facilitate learners' agency by freeing them from curriculum and instruction. Furthermore, it should be process-oriented and participatory, with unpredictable outcomes, and should transfer the learning responsibility to learners. If this is to happen outside the makerspace setting and be transferred to the formal educational setting, the challenge becomes planning the curriculum. Thus, we must ask how learners choose what to learn. This question is important, as future learners must scrutinize, systematize, and make sense of the saturated information they encounter daily.

The second challenge is instructional. The makerspace pedagogical model poses the concept of constructionism, which implies learning by making, failing, and experimenting versus instructionism, which implies successful outcomes and avoidance of errors (Bevan 2017). If learning is not content-led but process-led, how should pedagogical instructions be formulated to ensure self-reliance in a formal learning setting? This is an important question because academic institutions are provided with the societal task of ensuring that learning outcomes are achieved to a satisfactory level (EURspace, 2019). At the same time, informal learning approaches and learning at work are gaining interest as a way for learners to adjust to the continually changing job markets by demonstrating their own agency and lifelong learning.

In addition to the challenges with content and instruction, inclusion is also a concern when cultivating maker pedagogy in formal education. Specifically, formal education must provide a learning experience for everyone, not just for those students who have a special interest in making or an accessibility to maker tools and communities. Furthermore, it must comply with a certain administrative, temporal framework with defined learning outcomes.

**Maker pedagogy in the design studio in formal education**

There are organizational and pedagogical practices that stand in the way of emulating makerspace pedagogy in formal education, but there are also limits in the theoretical approaches to implementing these emulations, which I will address in this section.

Literature reviews on the topic of maker technologies and learning (Vossoughi & Bevan 2014; Ford & Minshall 2019) have shown that pedagogues and researchers are discussing learner-centered theories, particularly constructivist and constructionist approaches regarding learning with maker technologies at all levels of education. In contrast, in studies on learning at work, network-based organizational theories are more present. In educational research, constructivism is especially visible in the recurring concepts of problem-based learning, followed by other constructivist concepts such as authentic, inquiry-based, and experiential learning (Pavel 2021). Constructivism assumes that learners generate their own construct of knowledge through experiences rather than by following instructions. Another theoretical construct often linked to learning by making is Papert's constructionism (Vossoughi & Bevan 2014), in which construction happens when the knowledge is put to practical use by learners. Maker pedagogy is also related to process-based learning inspired by design thinking such as pedagogical principles of hack, adapt, design and create (Bullock & Sator, 2016). The other approach to understand maker pedagogy relies on describing attitudes such as: (a) seeking know-ledge, (b) exploring opportunities, (c) assuming responsibility, and (d) embracing change; as well as types of competencies: creative thinking, collaboration, and communication Nadelson and Seifert (2016)

To study maker approaches to learning in formal education, the pedagogical setting of the design studio provides a useful research site for many reasons. It supports experimentation, failure, defining problems and designing solutions as part of the design process. The design studio is situational, includes maker technology media, and can be characterized by peer learning. In this way, the design studio can be seen as a formal education counterpart of informal makerspace pedagogy. The similarities continue when theoretical approaches are compared.

The design studio in literature has also been extensively linked to constructivism (Sawyer 2017), where learning is characterized by cycles of critical reflection, as described by Schön (2015). However, differences can be found, especially in the way expected learning and material outcomes are defined by curricula, codes of professional practice, and the pedagogue, who is visibly present in a design studio. Contrary to design pedagogy, makerspace approach is fully dependent on interests of the makerspace participants. Martin (2015) explains how learners in makerspace choose to make what is 'fun' and 'cool' for the maker group.

Regarding organizational practices, it is necessary to acknowledge that makerspace pedagogy is emerging in a specific sociotechnological setting. This setting is characterized by voluntary learning groups, three-dimensional (3D) printers, cheap sensors, and mini-personal computer components, such as Arduino. The challenge with these theories is that both constructivism and constructionism as well as process led learning theories put the learner at the center and neglect the effects of this rapidly changing sociotechnological environment.

## Research design: action research, direct content analysis and postphenomenology

This study focuses on practical application of maker pedagogy in a 3D printing course repeated over three years in formal design higher education. With each repetition, the course has been modified to facilitate maker pedagogy. Modifications were supported by analysis of a previous course and theoretical reflections. In this way action research methodology has been informed by pedagogical theory and evolving direct content analysis.

### Teaching design studio in cycles of action research

Action research is an effective methodology for enacting and studying changes caused by technological mediation in real-life research settings, such as a design studio (Swann, 2002). Thus, it was chosen for this research, which had the main goal of cultivating learning and teaching practices in terms of creating new pedagogical approaches, relating these practices to relevant literature and theory, and elevating practitioners' professional accountability (McNiff 2014). Action research is a way for teachers to reflect on and improve their practice, and in this study, inciting maker pedagogy in the design studio gives action research an emancipatory quality. The methodology of action research is described as narrative writing in the first person, in which cycles of action and reflection inform each other, leading to transformation (McNiff 2014).

In this study, three cycles of action research were implemented through three repeated and modified six-week introductory courses, with a different group of 45 first-year students for each cycle. The course was set up to on the basic premises of design (Simon) such as defining user needs, translating them into product specifications, and constructing and forming artefacts to answer these needs. Students worked in groups in which they were required to frame problems, design solutions, and manage workloads on their own as explained in the results section, where one exemplary project is described (see Figure 4). As the participants were just entering their studies, very few were familiar with 3D-printing technology. The course was situated in a bachelor's program in product design in one of the three design schools at the university level in 'COUNTRY'. The study program has its roots in arts and crafts, with a tradition of workshop skills, conceptual design ideation, and materiality of design. This setting, therefore, incorporates the challenges of maker pedagogy in formal education, which is additionally burdened by temporal and administrative demands, as well as a diverse group of learners in terms of their familiarity with maker and design processes. Furthermore, a new 3D print lab had recently opened, and the department's management was motivated to put 3D printers into pedagogical practice with novice students. The first course was introduced at the end of the first year of the product design study in 2017, followed by the second and third in 2018. The study was authorized by the Norwegian Council for Research Data as research in one's own practice and according to its ethical standards. These standards include participant consent, anonymization, and secure data handling.

I engaged two experienced and qualified colleagues to be critical friends which is common in action research methodology (Wennergren, 2016). One was present during daily activities, and the other provided feedback on learning outcomes. Together they assessed grades for students. They were engaged in assessing and providing critical discussion on the changing course description and task description for the students. They also collected data when multiple student groups participated in activities at the same time. The head of studies at the department was involved and provided opinions on behalf of the department. This arrangement allowed me to observe the research setting as a pedagogical situation and avoid grading projects myself, which would be unethical. Action research allows for the collection of real-life data as well as first-person involvement. This means that the data include records of designing in action, where students, in teams, discuss both the development and purpose of their prototypes without the involvement of teachers and conduct interviews through which they reflect on the designing experience. First-person involvement means that the researcher is not a mere observer but takes part, taking concrete action to improve their own pedagogical practice.

The cycles of action research were supported by direct content analysis. This approach applies theory to determine classification topics in advance (Hsieh & Shannon 2005). The method allows for the exploration of existing theoretical concepts within the data material. In this study, the actionable phase involved the implementation and observation of the design course. Direct content analysis was used in the reflection phase to probe different theoretical approaches through classifications and to develop explanations for what was happening in the design studio to inform modifications to the design studio course.

The data material therefore includes course descriptions and pedagogical instructions developed by teachers as an action plan for the next cycle or a revision of a previous cycle. Evidence from the course activities was used to analyze and evaluate the practical pedagogical outcomes of these pedagogical instructions. Participant observation of prototype presentations was recorded, and notes were taken. Archival data material includes reflection notes about the course by students and design reports in which students were instructed to describe and reflect on their design activities. Artefacts themselves were useful material, as they represented how technological mediation influenced the design outcomes. This evidence from the course activities was used in this study to qualitatively assess students' abilities to translate pedagogical instruction into learning activities and realize their own agency. The citations used in the descriptions of the findings section are representative citations from the classification categories in the revision cycles of these data. The data were compiled and processed in NVivo software in the NATIONAL language, and the citations and conclusions were translated for the purposes of this article.

This new theoretical and pedagogical framework evolved in the process of recoding data in three cycles of field and literature research. Throughout the process, many of the theoretical classifications were either not relevant to the data material or did not provide explanations that could give new insights for the studio-based maker pedagogy, leaving the postphenomenological explanation as prevalent. The classifications are described in detail in coming section 2.3.

**Postphenomenological perspective: technologically mediated learning**

The sets of classifications emerging from the postphenomenological analysis of the data gave different explanations to the learner centered approaches. The postphenomenological framework sets the relationship between learners and the technological environment in which learning happens as the focus of pedagogical effort. Merleau-Ponty (1996) explained that meaningful, embodied learning means that human bodily capacities, such as the mental, emotional, and physical, in relation to environmental affordances and constraints are the preconditions for learning. Learning means changing and transforming oneself in relation to the environment. Consequently, postphenomenology does not address learning, at least not as a psychological process. Rather, it addresses the phenomenon of mediation between humans and machines. This technologically arbitrated phenomenology (Ihde 2003) implies that not only are technologies used by humans but that this interaction is reciprocal. Namely, technologies transform human perceptions by amplifying or reducing certain aspects of the experience, and they translate human actions by inviting or prohibiting humans to do certain things (Rosenberger & Verbeek 2015). Thus, human learning can be seen as an outcome of human–technological mediations and these transformations. This is distinct from constructionism, which sees technology as being used by learners to construct and internalize knowledge. In this way postphenomenology allow for sociotechnological understanding of learning with 3D printing.

3D printing is a complex and versatile technology, as it is capable of fabricating 3D objects of nearly any shape or geometry through only one operational process. The mass-production character of the process is enabled as a digital model can be converted into material layers (Iancu, et.al, 2010). As a result, the link between physical and digital models becomes interchangeable, in that material and digital artefacts become representations of each other.

3D printers have not disrupted production, distribution, and consumption because they are not as effective when scaled up in production (Marak, et.al., 2019). Instead, the disruption by 3D printers has occurred in education and design practice. In education, they have contributed to the emergence of informal learning forms, such as makerspaces. In design studios, 3D printers have enabled rapid prototyping methods that allow for the prompt and streamlined development and testing of prototypes. Yet, as a personal educational technology, 3D printers have brought a new set of affordances and dissaffordances to learners. They afford the sharing and editing of geometry through files at distances; mass production with iterations, which is further accelerated by using artificial intelligence for model simulation; and the geometrical complexity of fabricated objects, and all that without using series of specialized machines and need for safety training. Temporary dissaffordances include the material and functional examination of objects, as the 3D model is translated into a 3D print in a couple of hours. Thus, the adoption and adaptation of technology and the attainment of one's own goals through these mediative properties become the object of research and can be characterized as learning to, by, and through 3D print(ing).

**Adopting and adapting 3D printers and attaining goals by using them**

Three sets of classifications emerging from postphenomenological were essential for the direct content analysis of the collected qualitative data used in this study.

The first classification addresses skill by technological means, or how learners adopt the technology. This implies the extent to which learners manage to operate the technology and produce the intended immediate results with it. The more they use the technology, the less it obstructs them in their intentions, and the more it becomes *transparent* to them or, the opposite, remains *opaque* to them (Rosenberger & Verbeek 2015).

The second classification addresses inventiveness and encompasses how learners adapt technology to their practice. This refers to the extent to which the technology is meaningfully used for learners' objectives The more they establish practices around the technology to fit their needs, the more it becomes *sedimented* in their routines or, conversely, remains *multistable* or open to a variety of usages (Rosenberger & Verbeek 2015).

The third classification addresses the ability to implement, or how learners apply the technology to affect their environment to attain goals. This refers to the extent to which learners comprehend the possible outcomes of the use of the technology and how it will affect their own mediations with technologies. The more the learners take responsibility for mediations, the more they recognize their agency, changing their *field of awareness* (Rosenberger & Verbeek 2015) and tapping into the *potentiality* of the technology used. In contrast, the more they rely on the existing *field of awareness*, the more they use it in its *actuality* (Kiran 2015).

## Results: three course cycles of action research

### Research Cycle 1: challenges in constructivist pedagogy

The activities of a learner and a course manager at the department of product design can be described by design studio practice, which Schön (1985) observed and noted:

> *"Given an architectural program or brief and the description of a site, the student must first set a design problem and then go on to solve it. Setting the problem means framing the problematic situation presented by site and program in such a way as to create a springboard for a design inquiry. The student must impose her preferences onto the situation in the form of choices whose consequences and implications she must subsequently work-out all of the field of constraints." (6)*

Thus, for the purposes of this study, I presented students with an existing one-part handheld product as a *site* and instructed them to produce a *design brief* as a *design program* for which they were to analyze this product and critically assess it. From the analyses, they were to *frame the problematic situation*, impose *their preferences*, and test them through a series of physical prototypes, *working out* the *constraints* in material, processes, and functionality. Students were expected to implement and demonstrate new *imposed preferences* with each iterated prototype by testing and reflecting on them.

The focus of the course was students' development as design professionals and their personal approaches to the design process. The pedagogical method relied on individual tutoring, reflective journaling, prototype presentations, and collegial critique. The students were encouraged to manage their own design processes and acquire the skills needed for them. I had previously introduced 3D printing through lectures and live or video demonstrations as an optional technique. My intention was to observe how they could utilize 3D printing in a self managed process.

The overwhelming majority of the 28 students were reluctant to make prototypes. The process took two tutoring sessions and two weeks, during which the students discussed their ideas among themselves, often over rough sketches. Once they started building prototypes, they used techniques learned from the previous courses (See Figure 1). Only four of the students 3D printed their prototypes.

***Fig. 1: Starting from the problematic situation and defining preferences, students use the media and materials they are already familiar with, such as wood and metal to answer the assignment. On the image left, preference is gender neutrality, on the picture right is aesthetic congruency.***

*Revision 1*

The notable topic in reflection notes and interviews about the course was students' frustration with pedagogical instruction, which they characterized as incomplete, unspecific, confusing, and contradictory. This topic was also present in their reflections on design activities. Students struggled to formulate what they wanted to achieve with their designs and had difficulties accomplishing them. One learner said, ‘It took me half of the course to understand what the task was really about.’ Another directly addressed the inability to comprehend the expected outcomes of the assignment: ‘It was very difficult to understand what is expected in this course, what are the course requirements, and what should be the effect of our designs.’ This was also pervasive in participant observations, where learners asked for clearer instructions and insisted on practical guidance: ‘What is the right way to do this (assignment)?’ This topic was noted among the students who received top grades but still wondered why their work was perceived as good by teachers.

The adoption of media was mostly about the making of prototypes, such as glazing, gluing, or woodwork. The attainment by means of technologies was described in terms of certain design concepts, such as ergonomics, material construction, and even gender-neutral form semantics, in the context of their user preferences. These topics emerged freely through the learners’ own critical analyses of the site, interests, and prototyping techniques. Accordingly, the students were not describing their designs in terms of intended design goals but as an ongoing discussion with tutors and colleagues and their critiques.

Only four students used 3D printing in their projects. In two of these projects, I found some evidence of adoption and adaptation where leaners had discussed their design processes through series of 3D prints. Regrettably, most of the students failed to adapt 3D printers for their goals.

At the end of the course, the critical friends noticed this disconnect between the students’ intentions and use of media. They assessed that the major issue with the student projects was a lack of meaningful problem formulations or that the problem formulations were not addressed properly in the students’ design activities and prototypes. The critical friends noticed that there was a ‘big split in the quality of the projects’ and that those who did exceptionally well showed great independence in their work. The critique from management was that 3D printers were not used, and that the department did not gain new insights into the 3D printing lab from this course.

The central idea of constructivist pedagogy is to allow learners to decide what and how they want to learn and support them in their own inquiry (Montessori 2013). However, the tension between the quality of autonomous learning and the lack of effectiveness in direction (Sterling 2010) seems to favor learners who are already autonomous. This collides with the values of accessibility to learning, inclusion, and respect for learners’ integrity. Schön (1985) described the relationship between learner and tutor through the model of master practitioner and apprentice in a design studio. I could identify with this model with uneasiness, as I was not teaching students a transparent design practice. Instead, practice was delivered spontaneously, distilled from personal experience, and tailored to the individual learner. This highlighted the issue of power and threatened the prospect of educating critical learners.

According to the literature, the challenges that I met do not seem to be unique. A qualitative study of architecture students in a design studio (Hokstad et al. 2016) portrayed the individual voices of learners and their struggles coping with the ambiguity of the design learning process. Schön (1987) described design learning as a paradox in which students are instructed to learn by simultaneously determining what designing is and how to do it. Thus, according to this idea, my instructions were not only misinterpreted, but they were also unattainable. This is because the learners did not have enough practice performing the task and not enough understanding of design to organize their individual practices. These literature findings led me to doubt this pedagogical approach.

My own research, the input from my colleagues, and the literature review show that the actual challenges the students experienced involved analyzing the existing sites, turning analysis into a problem framework, and adequately addressing this framework through their prototypes. The random and unplanned use of technologies made the learning ineffective, as evidenced by the learners' struggles to materialize their ideas. This indicated that the transition in the autonomous learning processes and the use of maker technologies needed to be pedagogically sustained.

**Research Cycle 2: teaching by instructional design**

To support these transitions, we taught students digital modeling in workshops and online tutorials before the course started. The course itself consisted of two shorter assignments: an individual one and a group one. The aim of the assignments was to practically demonstrate and pedagogically support the learners' abilities to connect design methods, prototypes, and the problematic situations. Students received a design brief that included a detailed description of how to redesign a generic product to become a personal product for their colleague. We recommended that they conduct an interview with their colleagues, discuss form semantics by using mood boards and a semantic differential questionnaire, and finally iterate ideas through a series of 3D prints. We proposed relevant literature with methods on how to do this.

The second assignment was designed for groups of six students and was introduced as an action research process. Action research methodology was used to break up the framed design problem into observation, action, and reflection to be presented in a design brief. This design brief was missing text but had either images of existing products, mechanical parts generated by 3D printing, or constructions unique to 3D-printing technology. Students were instructed to formulate their own tasks around these manufacturing principles, complete the design brief, and keep modifying it throughout the design process, turning it into an instrument for reflection in their action research. The goal of the assignment was for students to learn how to conduct action research in their own practice and test their assumptions practically through 3D printing.

Throughout the first assignment, I explained the process, teaching them how to conduct and analyze interviews, use semantic differential analyses, and use various techniques when designing objects. Throughout the second assignment, I commented on their action plans in meetings and in the joint design brief posted online.

*Revision 2*

Students reacted strongly to pedagogical instruction in this cycle as well. However, this time, the learners described the instruction as overwhelming, too detailed, and difficult to follow, especially when relating to the first assignment: 'The instructions were very detailed, and if you don't follow up fast, you easily start lagging behind.' This was especially noticeable in the second assignment when adapting various media to the students' own projects. The detailed instruction was also incomprehensible for some learners, as their own questions were unanswered by the methodology prescribed by the given methods. Students struggled to adapt multiple methods, such as the mood boards, semantic differential analysis, and 3D printing in the first assignment. In their comments, the topics revolved around the appropriate use of mood boards and semantic differential analysis: ‘I was struggling to understand how to use semantic analysis and how those moodboards and adjectives are expected to affect the shape design’.

The other pronounced topic in the direct content analysis was about design activities, as students described their group work experience in the second assignment. As there was not enough time for the adoption process, the students who were not yet competent in digital modeling took on other tasks in the group, such as writing the report, which further diminished their opportunities to become familiar with 3D printing. They claimed that the lack of participation in activities using 3D printing was demotivating. Students for whom 3D-printing technology was not transparent enough seemed to fail to sediment the technology in their practice.

Concerning the adoption of 3D printers, one very pronounced topic was the learners’ struggle to predict the proportions of the 3D-printed artefacts, as they had a ‘different feel of it on the screen’. The other discussion was temporal organization, such as planning when to use 3D printing, as it could be time consuming, depending on the size and details of the artefact. Students also discussed how to optimize their design process to accommodate this issue by printing overnight. This, as well as the mechanical properties of the 3D-printed parts, was a central issue when learners were deciding whether to use other making processes, such as laser cutters, for parts of their artefacts. These topics indicated that 3D printing was becoming more transparent to learners and that new practices were emerging and turning into sedimented routines, realizing student agency.

The critical friends noticed that the students produced more and better detailed prototypes than the previous class did (figure 2). They also noted that more of the students could explain how their prototypes addressed their problem formulations. In this course, the students’ grades were grouped in the middle and upper ranges of the grading scale. In addition, 3D printing became the living practice in this course, and the head of studies initiated moving the course to the very beginning of the first year. The rationale for this was that students need to be exposed to this way of conducting the design process before they get extensive training with various workshop machines.

In the second cycle, the instruction was defined by a curriculum that included topics such as form semantics, product construction, user interviews, and action research as the method. In that sense, learning was defined by the instructional design in formal education and could not be described as learning freed from the curriculum and instructions. The personalized approach to the design process and skill acquisition was abandoned. The students were comprehensively instructed in a variety of skills and introduced to the topics they were instructed to investigate. In the third assignment, learners were provided with a starting point that they had to problematize, media that they had to utilize, and a method for their inquiry.

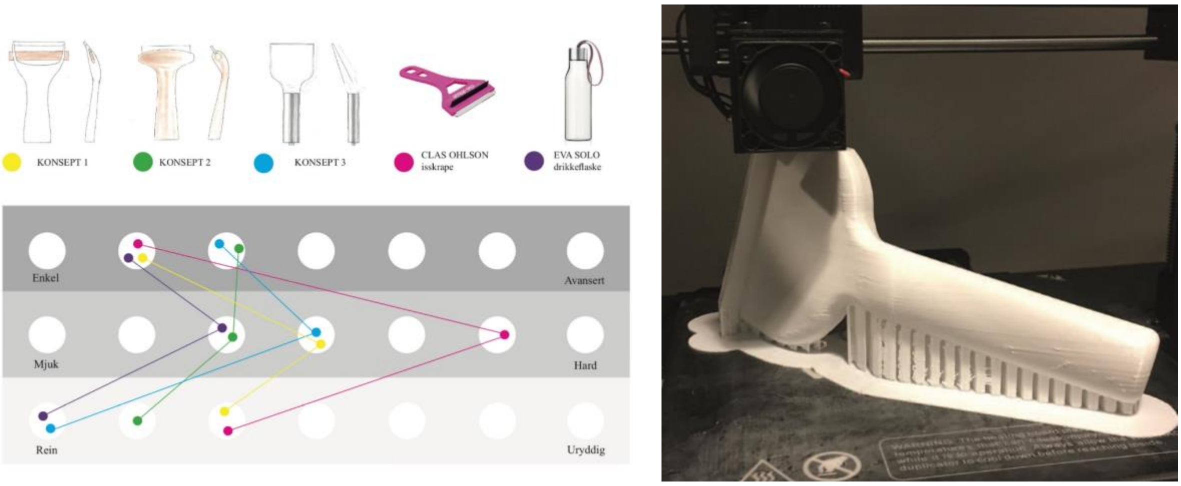



***Fig. 2: Example of a two week assignment on form semantics. Semantic analysis and 3D print methods were used as defined in the course instruction.***

In this cycle, my role as a pedagogue seemed less personal, as it relied on theory and method rather than on my experience as a design practitioner. I found my work more in line with what Kalantzis and Cope (2010) defined as that of an instructional designer. Instructional design should engage learners in their learning by providing adequate experiences of learning for the intended learning goal. According to some researchers (Halverson & Sheridan, 2014; Martin 2015), emulating a makerspace learning setting in formal education is challenging because of the risk of tool-centrism and curriculum-centrism, which are both problematic for a maker mind-set and an open approach to learning.

Thus, the perceived improvement in results seemed to rely on comprehensive instruction related to the content from the curriculum, which diminished the need for learners to engage in problem framing and hid the incompetencies in 3D printing of the students in groups. This approach seemed to benefit design results more than student agency, as it did not sufficiently expose learners to critical reflection. My colleagues shared a different viewpoint, underlining that it is positive for students' motivation to experience proficient implementation of their designs so early in their studies.

**Research Cycle 3: relation and mediation-driven learning**

The third iteration of the course was scheduled at the very beginning of the school year. This meant that my colleagues and I had to implement training in digital modeling as part of the course. The course therefore consisted of three assignments. The first included training in digital modeling, and the second and third were repeated from the previous course, with modifications. First, action research was introduced as a method at the very beginning of the course for all three assignments. Second, the course was organized so that the use of 3D printing as a medium in the assignments was predetermined, but the specific use was not. In the first assignment, the students were given sketches of an unfinished abstract artefact and asked to finish it as a digital model and a 3D print. The second assignment was repeated, but this time, it was a group assignment to redesign a product for each other. However, this time, students were instructed to propose their own methodology and implement it in the cycles of action research using 3D printers. The third assignment was modified in two ways. First, the groups consisted of three students, who were instructed to participate equally in the production of prototypes and a brief. Second, the students were not given any content instruction other than to write a design brief before they used 3D printers. The design brief was to document their action research plan, which they fully controlled. To help them accomplish the first assignment, we gave feedback and provided video tutorials to students on how to create digital models. For the second and third assignments, we offered assistance with design briefs for coherence and the practical aspects of the project.

*Revision 3*

Even though some students pointed out that the instruction was overly detailed and others said it was confusing, the more common opinion was that it was complex, demanding, and difficult. The word 'challenging' was used in multiple instances. They noted a 'steep learning curve' when they evaluated the adaptation of the 3D-printing technology: 'It was challenging but insightful. We found out that many of the things we wanted to make had to be adjusted or discarded in the process.' They also expressed a need for a more holistic understanding of the process in which they were involved: 'I wish I had had a better overview of what we were doing beforehand.'

Students also showed more agency in overcoming 3D printer dissaffordances when adopting this prototyping technique (figure 3). For example, challenges with delayed haptic feedback were repeated in seven of the projects. The learners described this as having to adjust and reprint their artefacts to get the right proportions. Another topic that emerged involved modifying and reproducing digital files on 3D printers with different mechanical material properties.

***Fig.3: Example of a two week assignment inspired by affordances and dissaffordances of 3D printers: holder for tablet -flat packed design is fast to print and without support material, while being easy to store and transport.***

In the adaptation process, learners struggled to decide what 3D printing as a medium was best suited for so they could take advantage of it in their projects. As in the previous research cycle, the printing time dictated work routines in the 3D printing lab, including printing overnight. When attaining goals through 3D printing, learners took advantage of the ability to distribute digital files over internet sites for personal reproduction and connect to potential users of the product. The other commonly noted topic for using unique 3D-printing techniques involved complex geometries, such as enclosed hinge systems and Voronoi structures. Finally, some of the students talked about how they researched on the internet to learn more about the application of 3D printers.

In the third research cycle, the instructions were aligned with the classifications informed by postphenomenology. The assignments were designed to support learning from adoption to adaptation and attainment. In the first assignment, I supported adoption by sedimenting the purpose of the 3D printer and providing a sketch so that learners could gain transparency of the tool. In the second assignment, I encouraged experimentation by providing a social context but not giving a precise purpose of the tool, letting learners explore its multistability. In the last assignment, by focusing on the construction of the objects, learners had to use their sense of transparency and the multistability of the tool to contemplate possible constructions for their designs in teams.

In this research cycle, my role as a pedagogue was still based on instructional design. However, the instructions were aligned with the sociotechnological environment of the studio rather than the curriculum or learner-defined inquiry. Tutoring was also based on discussion about what could be done with 3D printers and entirely left out design critique.

My colleagues evaluated the results of the projects in terms of accomplishment and quality, similar to their process for the previous course. The grades declined slightly toward the middle of the scale. The research material showed that students were more engaged with 3D-printing techniques, as the strategic use of their affordances was more pronounced.

**Example of learner–technology mediation in a design course**

Most of the data sets included personal reflections or discussions in which learners evaluated different aspects of the design challenge through a series of design proposals. In the data sets, the classifications were shifted interchangeably. The classifications also appeared on two levels in the context of the usage of the 3D-printing technology as well as on the emerging technology that the learners designed.

Learners explained their chosen task through the changed field of awareness and technologies' potentiality: 'We wanted to use 3D printing to make fasteners because we can make them complex, test, modify, and reproduce them quickly.' They assessed the multistability of the newly invented fastening technology: 'Clips could allow modifying the storage; it could be modular.' They discussed the new modular clipping technology and its potentiality: 'We want to design a system for storing clothing, but we haven't landed on that yet.' They further discussed how this could be done by 3D printers, sedimenting 3D printing into their own practice: 'We will 3D print clipping modules that hold the plywood structure.' Finally, they turned this into comprehensible instruction: 'The most important thing in the first round is to make sure the modules hold the structure, and they are easy to mount and demount for one person.' They further discussed how transparent this new modular shelf technology could be: 'We will not have time to test this on users. We cannot claim it is easy to adjust the shelves.' Finally, they created a more comprehensible and manageable task: 'Let's make a modular bookshelf that you don't adjust too often but can fit in any interior. We can then demonstrate different shelf configurations' (see Figure 1). Their design and learning topics were defined by the allowances and prohibitions of the fastening technology, as was the new practice that emerged from the mediation between learners and 3D printers.


***Fig. 4. Modular shelf system made by a group of six first-year students in two weeks.***

## Discussion: alternative pedagogical framework for the design studio

This study exemplifies the challenges of inciting maker pedagogy in formal education such as design studio. The challenges for learners involve the lack of experience in organizing one's own project-based learning. The challenge for pedagogues is generating open learning inquiry without falling back on tool-centric instructionist or curriculum-centric approaches. Through iterative action research, this study provides a critique of and an alternative to constructivist theories, especially regarding the lack of explanation about the role of technologies in learning and the transfer of the responsibility for learning to learners. Thus, a step forward in pedagogy was visible when the given instructions evolved from problem framing and design specifications to the technical affordances of 3D printers. When it comes to responsibility for learning, this study indicates that, when pedagogical instructions are more aligned with the social and technological environment rather than predetermined content or process in the design studio, they become more comprehensible to learners.  Regarding the role of technology in pedagogical instruction, this study demonstrates how tool-centric instructionist approaches can be expanded beyond skill acquisition toward adaptation of and attainment through technologies and could be an alternative to constructivism and constructionism. This study provides a new perspective on design studio pedagogy for the future, where the influx of novel technological media, its utilization, and the development of new technological practices will become more important. It illustrates how networked technological learning, common for learning at work can be applied in formal education.

### Content and instruction in maker pedagogy

Let us return to the questions posed in the introduction regarding on the choice of content and instruction in maker pedagogy in a formal educational setting. In maker pedagogy, media affordances and the social context, rather than curricula or the prescribed processes, determine what is going to be learned. If pedagogues want to introduce specific content, they should introduce new actors into the course, such as a specific user and client in the design studio, or a member with different preferences in makerspace rather than only new literature or group activities. Students would have to engage with topics characterized by the needs of these actors to realize their own agency. In the repeated design courses in this study, students' own interests and design inquiry were framed by the affordances of 3D printers and their social groups, much like in makerspaces. Some of the student groups connected to external networks; for example, one group decided to distribute their product through a website for digital model sharing, where they engaged with a group of users who provided feedback.

When it comes to pedagogical instruction in maker approach in formal education, the role of pedagogy is to support learners' own agency and awareness rather than their acquisition of skills or construction of knowledge. Learners' agency directly depends on their sense of technological transparency, and pedagogical instruction must incorporate issues of the learners' technological environment. While technology is opaque to learners, instruction is meant to support their persistence in mastering it. Once the technology becomes transparent, instruction is meant to support learners' ability to make decisions independently. Therefore, to be understandable and attainable, the instruction must encompass learners' sociotechnological environment rather than only curriculum topics or the process. In a future with a workplace characterized by the influx of new technologies, the goal of maker pedagogy should be the ability to realize one's own agency through technologies and the responsibility for one's own doings.

In this sense, a pedagogue becomes a facilitator of the sociotechnological environment. From the postphenomenological perspective, by bringing 3D printers into the classroom, a pedagogue is setting the meditative properties of 3D printers as a precondition for what can be learned and how. Learners in the design studio do not just use 3D printing to produce experiences and construct knowledge; instead, they use 3D print artefacts for a certain purpose. The 3D printer therefore mediates between them and their design intentions and sets the learning stage in which the social activity around using and utilizing 3D printers becomes the focal point of learning. In doing so, the set of technologies, including digital modeling, layer slicing software, and, finally, the 3D printer, helps shape the subjective experiences and objective reality for learners.

## Conclusion: Technologically mediated pedagogy in formal education

Postphenomenological perspective enables discussion about pedagogical challenges in design and maker contexts that does not solely rely on curriculum, instruction, and knowledge outcomes in formal education. Design and maker pedagogy seen from the postphenomenological perspective does not need to be framed by learners' critical reflection and design critiques by peers. Instead it is framed by what technologies can do and most importantly, what the needs of the learning network are. Design and maker pedagogy can be relationalist in the sense that the pedagogical intervention is directed toward human–human and human–technology relations rather than learners' construction of knowledge. This approach relies on the sociotechnological network to develop content, questions, activities, and suitable sustainable practices with technologies through a consensus generated by trial and error rather than on a design critique or curriculum plan.

Design and maker approaches in formal education beyond the design studio can occupy a niche between formal training, practice placements, and academic courses. This can be particularly beneficial in formal institutional settings when related to labs, workshops, and multiple actors, such as master's students who are involved in research projects. The benefits of maker pedagogy in formal education, compared to the abovementioned educational forms on the one hand and informal makerspaces on the other, are in the inclusion of learners on different levels and interests, as well as project process methods and critical awareness of one's own actions using technology.

This also makes it possible to describe design and maker approaches through the European qualification framework for course design. The framework provides an explicit and precise description of the knowledge, skills, and ability of the learner to apply these knowledge and skills autonomously and with responsibility (EURspace, 2019). Maker pedagogy emphasizes learners' autonomy and responsibility, which is defined in relational terms, that is, by the role learners take and the learning environments they occupy, rather than their skills and knowledge. Moreover, the instruction can be used to support the responsible use of technologies. As a variety of multistable, versatile technologies with high potentialities, such as artificial intelligence and mixed reality, continue to enter work life and classrooms, learners' agency will become increasingly important. As learners are supported by technologies, they will progress faster through intended learning outcomes and will also need to become more responsible in how they use these technologies. It is therefore essential to position maker pedagogy in the context of universities' role in facilitating learners' integrity and resilience (Levin & Greenwood 2008). In the end, these learners will be the ones who will have to cope with sociotechnological disruptions and who should think critically about the affordances, limitations of technologies and emerging ethical challenges when implementing sustainable development.

## Acknowledgments

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

## References

Bevan, B. (2017). 'The Promise and the Promises of Making in Science Education'. *Studies in Science Education 53* (1), 75-103.

Bullock, S,M., & Sator, A,J. (2017) 'Making' as a catalyst for reflective practice, *Reflective Practice*, *18 (2), 244-255*, DOI: 10.1080/14623943.2016.1268118

EURspace. (2019). 'Framework for Defining Learning Outcomes (Knowledge, Skills, Competence)'. Retrieved from https://eurspace.eu/ecvet/pedagogicalkit/framework-for-defining-learning-outcomes-knowledge-skills-competence/EURspace. Accessed 13 March 2023

Ford, S., & Minshall, T. (2019). Where and how 3D printing is used in teaching and education. *Additive Manufacturing, 25,* 131-150. https://doi.org/10.1016/j.addma.2018.10.028

Godhe, A.-L., P. Lilja, & N. Selwyn. (2019). 'Making Sense of Making: Critical Issues in the Integration of Maker Education into Schools'. *Technology, Pedagogy and Education 28 (3),* 317–328.

Halverson, E. R., & K. Sheridan. (2014). ‘The Maker Movement in Education’. *Harvard Educational Review 84 (4),* 495–504.
Hokstad, L. M., G. Rødne, B. O. Braaten, S. Wellinger, & F. Shetelig. (2016).
‘Transformative Learning in Architectural Education’. In R. Land, J. H. F. Meyer, and M. T. Flanagan, *Threshold Concepts in Practice,* (pp. 321–333). Rotterdam: Springer.
Hsieh, H.-F., & S. E. Shannon. (2005). ‘Three Approaches to Qualitative Content Analysis’. *Qualitative Health Research 15 (9),* 1277–1288.
Iancu, C., D. Iancu, & A. Stăncioiu. (2010). ‘From CAD Model to 3d Print via ‘STL’ File Format’. *Fiabilitate si Durabilitate [Fiability & Durability] 1 (5),* 73–80.
Ihde, D. (2003). ‘Postphenomenology–Again?’ Working Paper No. 3, Centre for STS Studies, University of Aarhus, Denmark.
Kalantzis, M., & B. Cope. (2010). ‘Learning by Design’. *E-Learning and Digital Media* 7(3), 198–199. https://doi.org/10.2304/elea.2010.7.3.198.
Kiran, A. H. (2015). ‘Four Dimensions of Technological Mediation’. In R. Rosenberger & P. P. Verbeek, *Postphenomenological Investigations* (pp 123). London: Lexington Books.
Levin, M., & D. J. Greenwood. (2008). ‘The Future of Universities: Action Research and the Transformation of Higher Education’. In P. Reason and H. Bredbury, *The SAGE Handbook of Action Research: Participative Inquiry and Practice*, (pp. 211–226). London: SAGE.
Marak, Z. R., A. Tiwari, & S. Tiwari. (2019). ‘Adoption of 3D Printing Technology: An Innovation Diffusion Theory Perspective’. *International Journal of Innovation 7 (1),* 87–103.
Martin, L. (2015). ‘The Promise of the Maker Movement for Education’. *Journal of Pre-College Engineering Education Research (J-PEER)* 5 (1): 4.
McNiff, J. (2014). *Writing and Doing Action Research*. SAGE.
Merleau-Ponty, M. (1996). *Phenomenology of perception*: New Delhi: Motilal Banarsidass Publisher.
Montessori, M. (2013). *The Montessori Method*. New Brunswick: Transaction Publishers.
Nadelson, L. S., & Seifert, A. L. (2016). Putting the pieces together: A model K-12 teachers educational innovation implementation behaviors. *Journal of Research in Innovative Teaching, 9(1),* 47–67.
Pavel, N. (2021). ‘Education for Resilience with Emerging Technologies: A Qualitative Study on the Learner–Media Relationship in Product Design Education’. PhD diss. Oslo Metropolitan University
Quinn, H., & P. Bell. (2013). ‘How Designing, Making, and Playing Relate to the Learning Goals of K-12 Science Education’. In M. Honey and D. E. Kanter, *Design, Make, Play,* (pp. 35–51). Routledge.
Rosenberger, R., & P.P. Verbeek. (2015). ‘A Field Guide to Postphenomenology’. In R. Rosenberger and P.P. Verbeek, *Postphenomenological Investigations: Essays on Human-Technology Relations*, (pp. 9–41). London: Lexington Books
Sawyer, R. K. (2017, 2017/11/01/). ‘Teaching Creativity in Art and Design Studio Classes: A Systematic Literature Review’. *Educational Research Review* 22 (Supplement C), 99–113. https://doi.org/https://doi.org/10.1016/j.edurev.2017.07.002
Schön, D. A. (1985). *The Design Studio: An Exploration of Its Traditions and Potentials*. London: RIBA Publishing.
Schön, D. A. (1987). *Educating the Reflective Practitioner: Toward a New Design for Teaching and Learning in the Professions*. San Francisco: Jossey-Bass.
Schön, D. A. (2015). ‘Learning to Design and Designing to Learn’. Paper presented at the International Conference on Theories and Methods of Design, May, 1992.

Sterling, S. (2010). ‘Learning for Resilience, or the Resilient Learner? Towards a Necessary Reconciliation in a Paradigm of Sustainable Education’. *Environmental Education Research 16 (5–6),* 511–528.

Swann, C. (2002). Action research and the practice of design. *Design issues, 18(1),* 49-61.

Vossoughi, S., & B. Bevan. (2014). ‘Making and Tinkering: A Review of the Literature’. *National Research Council Committee on Out of School Time STEM 67,* 1–55.

Wennergren, A.C. (2016). ‘Teachers as Learners–With a Little Help from a Critical Friend’. *Educational Action Research 24 (2),* 260–279.

# Effects of Curriculum Intervention on Divergent Thinking Abilities

**Gökçe Ketizmen, Eskisehir Osmangazi University, Turkey**
**Hakan Keleş, Eskisehir Osmangazi University, Turkey**

## Abstract

The primary objective of this study is to evaluate the divergent thinking abilities of first-year architecture students who are currently enrolled in a course focused on divergent thinking in architecture. The statistical analysis of student's studio works with Wallach Kogan`s divergent thinking pre/post-tests results demonstrated that the post-test score for verbal stimuli fluency was higher than the visual post-test score. In addition, the post-test score for visual flexibility was higher than the verbal post-test score. In originality students got the highest scores in post-tests both in visual and verbal tasks. Besides, the correlation analysis indicated a strong correlation between fluency and originality. These results revealed that design training considerably enhances students' capacity to produce original ideas both in visual and verbal thinking. In terms of their ability to create considerably more and qualified ideas on related themes students demonstrate more improvement in their verbal reasoning abilities than their visual reasoning skills. The present study determined that curricular intervention in the first semester training where the instructor emphasized development of divergent thinking skills improved students' both visual and verbal divergent thinking skills, to a greater degree in originality and to a lesser degree in fluency and flexibility in idea generation.

## Keywords

divergent thinking, first-year architecture students, design training, Wallach Kogan`s divergent thinking test, Statistical Analysis (SPSS)

## Introduction

In light of the significance of divergent thinking (DT) in design training, there has been a growing emphasis on developing creativity through training in divergent thinking abilities (Coleman et al., 2020; Doron, 2016; Raef et al., 2022; Rao et al., 2021; Sopher, 2020; Sowden et al., 2015; Sun et al., 2020; Tran et al., 2020; Van de Kamp et al., 2015). Divergent thinking is considered essential for creativity, which suggests that design training focusing on alternative thinking may be more effective in fostering divergent thinking (Rao et al., 2021). Sun et al. (2020) suggest that training in creative thinking, particularly divergent thinking, has shown promising results for enhancing creativity in higher education and corporate contexts. Similarly, Raef et al. (2022) asserted that students with divergent thinking were more creative. In addition, Tran et al. (2020) conducted a 14-week undergraduate course on creative approaches and found a substantial improvement in participants' divergent thinking in the post-test. Another study revealed that design thinking training promotes ideational fluency and elaboration (Rao et al., 2021).

Within the realm of architectural education, particularly in the context of design studios, students are consistently tasked with the responsibility of identifying and implementing resolutions to various challenges. The term 'designing' can be understood as the act of 'creating,' therefore emphasizing the importance of fostering creativity on an ongoing basis (Hassan, 2016). The inclusion of architectural design education has the potential to not only foster product innovation, but also to strengthen the process of decision-making. The assertion can be made that the primary goal of architectural design education should be on the resolution of design difficulties. This assertion is based on the understanding that creativity inevitably encompasses the process of problem-solving. The problem-solving process necessitates the utilization of both divergent and convergent thinking processes, which are crucial in producing a novel solution as the result of the design process. Architectural education assumes a significant role in creating curriculum that facilitate the cultivation of divergent thinking skills among students, given the inherent requirement of this discipline to challenge established cognitive frameworks.

Mayahi and Mazhari (2023) argue that creativity holds the highest priority and is an essential component of architectural education. The utilization of divergent thinking (DT) empowers a designer to steer their creative process towards a wide range of distinct and expansive possibilities, so exerting a substantial impact on the uniqueness of their work. The integration of creative education within architectural education, particularly in architectural design courses, is of utmost importance. The authors undertake an examination of creative education and its incorporation into the realm of architectural education, with a specific focus on its integration within architectural design courses. In conjunction with facilitating a two-day workshop, the research study procured data from library sources and solicited student responses via a questionnaire. The outcomes of the study indicate that architecture students exhibit a deficiency of knowledge pertaining to creativity and its cultivation. The concept of creativity is often perceived as ambiguous or unknown by a significant portion of individuals. The proponents assert that the incorporation of assignments within the curriculum, particularly in introductory and foundational courses, is crucial for familiarizing architecture students with the notion of creativity and creative education, in order to cultivate and enhance their creative abilities.

As one of the central components of creativity, DT is the capacity to generate various solutions in response to a specific stimulus or problem (Guilford, 1967). DT, which entails the ability to produce ideas, facilitates the resolution of unresolved problems by generating numerous original alternatives or solutions belonging to the same or mutually exclusive conceptual categories or types of responses (Palmiero et al., 2022). It's a cognitive process that diverges in multiple directions. Runco (2008) further expounded on this concept and defined divergent thinking tests as tools that "estimate the potential for creative problem-solving." This perspective underscores testing as estimations and possibilities rather than as guarantees of creative behavior, which stands in stark contrast to the notion equating divergent thinking with creativity (Runco & Okuda, 1988). Divergent thinking is a notably open and unrestricted intellectual exercise characterized by an abundance of connections and potential answers. It empowers individuals to venture beyond the confines of their experiences. According to Guilford (1950), in the realm of DT, a person can construct a novel idea in a situation despite limited evidence and a lack of prior knowledge. Divergent thinking often occurs spontaneously and leads to the rapid generation of multiple ideas (Raef et al., 2022)."

Divergent thinking tests are widely used in numerous studies to assess divergent thinking abilities (Dumas & Runco, 2018; Guilford, 1950; Mumford et al., 2008; Silvia, 2008; Silvia et al., 2008; Torrance, 1974; Wallach, 1970; Zeng et al., 2011). Guilford (1956) originally introduced DT based on the Structure of Intelligence (SOI) framework and methods for evaluating DT. Guilford proposed several indices for DT assessments, including fluency, flexibility, originality, and elaboration, which represent theoretically distinct DT characteristics (Peak, 2003). These indices have been predominantly used in research (Torrance, 1972, 1974; Wallach & Kogan, 1965). Wallach and Kogan (1965) aimed to develop metrics that could describe an intelligence-independent, cohesive aspect of creative thought, distinct from Guilford's framework. They introduced tests such as Instances, Uses, Similarities, Line Meanings, and Pattern Meanings. The utilization of multiple tests is partly influenced by the concepts of creativity and psychometric theory, suggesting that the most reliable assessments are based on multiple indicators (Cheung et al., 2004; Cheung & Lau, 2010; Lemons, 2011; Lissitz & Willhoft, 1985; Richards, 1976; Runco et al., 2016; Silvia et al., 2009; Sowden et al., 2015). Divergent thinking tests serve as predictors of creative performance rather than criteria (Wallach, 1970) by evaluating individuals' idea generation skills through the generation of ideas. These tasks measure idea generation capacity, including ideational fluency (the number of appropriate responses), flexibility (the number of distinct conceptual categories), and originality (the quality of responses) (Reiter-Palmon et al., 2019). Overall, divergent thinking tasks provide a good, although underutilized, tool for statistically assessing changes in creative thinking due to training (Demirkan & Afacan, 2012). In DT activities, participants are required to generate new thoughts or interpretations on a given input. DT tests thus provide the evaluation of an individual's ability to generate novel ideas under specific (controlled) task and stimulus settings (Erwin et al.,2022).

One of the primary objectives of the architectural studio is to impart the fundamental design skills necessary for generating design solutions. Existing literature suggests that design education has effectively enhanced divergent thinking abilities. This study's primary aim is to assess whether a one-semester design studio program can enhance the divergent thinking capabilities of architecture students. The research seeks to ascertain the impact of curricular intervention on divergent thinking skills within the first-year design studio. Two distinct measurement tools were employed: 1) students' design studio projects and 2) Wallach and Kogan's tests of divergent thinking. The choice of the Wallach and Kogan test is due to its content overlap with the studio projects, as the test shares certain aspects with the design works. The study endeavors to evaluate students' divergent thinking skills using four studio works completed as part of the 'Thinking in Architecture Design' course and Wallach and Kogan's divergent thinking tests. Pre- and post-tests were administered at the course's outset and conclusion to gauge whether the course had a positive impact on students' divergent thinking skills. The assessment criteria included fluency, flexibility, and originality as indicators of divergent thinking. For data analysis, the research utilized SPSS software. The Wallach and Kogan's divergent thinking test battery, based on several previously established scales, was employed to examine changes in divergent thinking abilities among first-year architecture students with no prior design knowledge following one semester of architectural coursework. The study involved a relatively small sample (N = 40) of first-year architecture students at Eskisehir Osmangazi University, Eskisehir, Turkey. These students completed the divergent thinking test battery at the beginning and end of their first semester during the fall of 2022-2023.In summary, the study utilized various assessment methods to determine how one semester of architecture education could enhance students' divergent thinking abilities.

## Method

### Participants

The data was obtained from a cohort of 40 first-year undergraduate architecture students during the Fall Semester of the academic year 2022-2023 at Eskişehir Osmangazi University's Department of Architecture in Turkey. During the preliminary stage of evaluation, a total of 160 studio works (SW) were considered as assessment instruments. The mentioned design works were produced by a cohort of 40 students and subsequently submitted for evaluation as part of four separate studio assignments. During the second phase of assessing DT abilities, a survey was administered to the identical group of students at the commencement and conclusion of the academic term. Prior to commencing the survey, all participants were mandated review and sign a consent form carefully created by the authors of the study. The lecturer apprised the students that the examination would be administered through the internet survey tool, SurveyMonkey, accessible at http://surveymonkey.com. The participants were provided with the survey link, along by instructions stating that they had the freedom to allocate as much, or as little time as required to fulfill the assigned tasks. From the group of 45 students that were registered in the course, a subset of 40 students was chosen for further analysis. This subset consisted of an equal distribution of 20 male and 20 female students. The assessment rejected the remaining five students due to their failure to achieve the requirements of the design task. Every participant underwent DT pre- and post-tests at the commencement and conclusion of the 2022-2023 Fall semester, specifically in September and January. The participants were instructed to generate a maximum number of responses for the DT tasks. The participants were provided with instructions that emphasized the insignificance of spelling accuracy and encouraged them to generate and record as many solutions as possible in order to optimize their performance. The completion of the exercise was not bound by any precise time constraint. In order to mitigate potential bias, three raters who were independent from the study were enlisted to evaluate the DT and SW tasks using a standardized scoring methodology. Furthermore, a third evaluator was chosen for the study, who is a scholar from the same department and possesses comparable knowledge to the two original raters (authors). Following the collection of participants' SW and DT responses, the evaluation process was initiated. The raters completed comprehensive training in order to effectively evaluate tasks and works, both on an individual basis and as a group. After receiving training, each of the three raters proceeded to individually rate the student works and DT test results.

### Measures

The study employed two distinct instruments: students' design studio projects and Wallach Kogan's divergent thinking assessments. These instruments were utilized to investigate whether the 'Thinking in Architecture Design' course had a positive or negative impact on the development of students' divergent thinking skills. To assess the changes, pre- and post-tests were administered at the beginning and end of the design course. The reason for using Wallach Kogan's tests of divergent thinking lies in their direct relevance to the design studio approach. In this approach, visual and verbal stimuli serve as primary tools for architectural design thinking in the studio.

*Studio Works*

The curriculum for the 15-week, one-semester 'Thinking in Architecture Design' course includes one 50-minute class each week. Throughout the semester, ten design assignments were developed, but this study focused on four specific assignments. These four selected studio assignments (refer to Table 1) had an equal number of lessons and resulted in a series of design projects in which students were required to articulate and visualize design concepts through architectural representations. Their task was to accomplish this in an original manner, and students received credit for their efforts. Two of the four selected student works are titled 'Abstract Skyline' and 'A Container Composition,' with the aim of enhancing students' visual thinking abilities. The remaining two works, 'Life of X' and 'In the Woods,' are designed to improve students' verbal thinking abilities (see Table 2)The four assignments were designed in a sequence from simple to complex. In the first visual exercise, “Abstract Skyline”, students were instructed to create imaginary city silhouettes using given substrates. Based on visual stimuli, they were expected to create a pattern with simple 2-dimensional shapes. The ways in which organic and geometric shapes would come together on a horizon line, the relationships between each shape and the composition, and their qualitative characteristics as parameters need to be discussed linearly. The final products should not only be an abstract city silhouette, but also demonstrate a highly detailed visual basic design assignment. Using the diverse shapes as thick/thin, linear/nonlinear, horizontal/vertical, angular/curvilinear would bring up the quality of each work.

The second exercise was titled 'A Container Composition' ***.*** The primary objective of this assignment was to transform an abstract three-dimensional Cartesian space into a tangible architectural space. Initially, students were tasked with visualizing a three-dimensional composition using several rectangular prisms of identical dimensions. Subsequently, they were required to illustrate this composition from an isometric/axonometric perspective. Following this, students were instructed to create a living environment by incorporating elements such as human figures, plants, and other architectural visualization features. These added elements, when viewed from the same perspective, conveyed the intended environment as a container-based defined space. The purpose of these two ***visually oriented*** exercises was to enhance students' decision-making and problem-solving skills through the use of diverse visual tools. In the assessment of the final products, key criteria included the richness of content, the utilization of both 2 and 3-dimensional representation techniques, and an awareness of concrete and abstract spatiality, rather than students' drawing abilities."

The third student work was titled 'In the Woods,' which was a verbal-based exercise. The objective of this exercise was to challenge students to imagine themselves lost in the woods and create a survival scenario. Each student crafted a storyline explaining how and where they became lost, whether they were alone, and what tools they had at their disposal. These imaginative decisions influenced their narratives and assisted them in devising a plan for overnight shelter. Within this framework, each student provided simultaneous verbal and visual instructions for creating a shelter. They specified details such as how to fell a tree for the structural elements of the shelter or how to transport water for making mud, among others. Their original ideas for problem-solving at each stage were the primary focus of the exercise. As a final product, they produced a poster containing each step of the entire building process. The final exercise, titled 'Life of X,' was a verbal-based project that challenged students to create a character and write a short story about their daily life. Students were tasked with describing the character's living conditions, including their urban environment, the interior of their home, and the objects they used daily. The goal was to produce a realistic, reality-based linguistic narrative, with no additional restrictions on the creative process.

***Table 1. Content of the students work***

| Activity | | Description | Assignment instruction | Scoring |
|---|---|---|---|---|
| **Visual Stimuli (ViS)** | | | | **Fluency:** Students cannot provide ideas; 0<br>Students can come up with one to two ideas: 2<br>Students can come up with three or more ideas: 4<br><br>**Flexibility:** Students are not able to provide ideas/ methods;0<br>Students can come up with one to two ideas/methods; 2<br>Students can come up with three or more ideas/ methods: 4<br><br>**Originality:** (Students do not general ideas/ common ideas and no originality; 0,<br>Students come up with moderate unique ideas; 2,<br>Students come up with very unique ideas; 4<br>(Jamal et al.,2020) |
| | **SW1. Abstract skyline.** | **Visualize an imaginary cities' skyline.** | *Draw an imaginary city skyline using organic and geometric 2-dimensional basic shapes. Use basic design principles as hierarchy, contrast, balance etc. The more you can give details, the better.* | |
| | **SW 2. A container composition.** | **Consider rectangular prisms as containers.** | *Create a 3-dimensional composition of rectangular prisms, consider it as a container architectural project and render it in isometric or axonometric perspective by drawing. The more you add aspects such as figures, furnishing and planting etc., the better.* | |
| **Verbal Stimuli (VeS)** | **SW 3. In the woods.** | **To spend a night in the woods safely, imagine the process of building a shelter.** | *Assuming that you lost in the woods, write down each step of building a shelter process by local materials. The design should depend on your narrative like how long you will stay and what kind of tools you have.* | |
| | **SW 4. Life of "X".** | **Generate a story of a person's daily routine.** | *Imagine a character and generate a daily life for him/her. Write down and draw the details of environment and objects according to your narrative.* | |

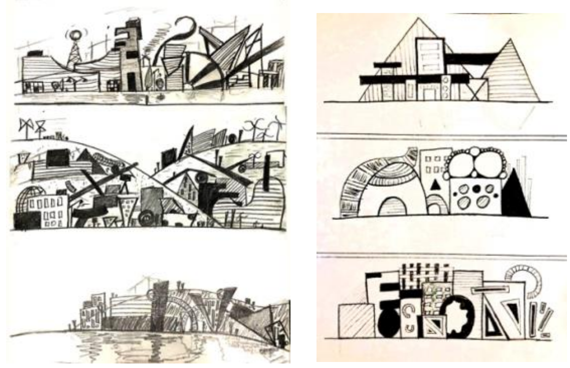
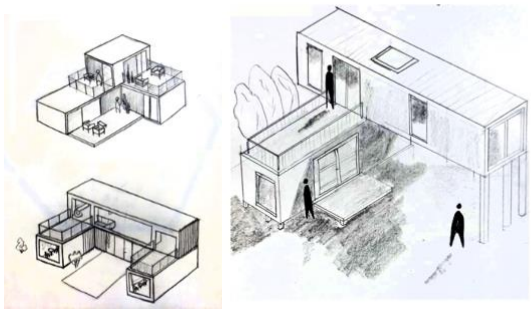
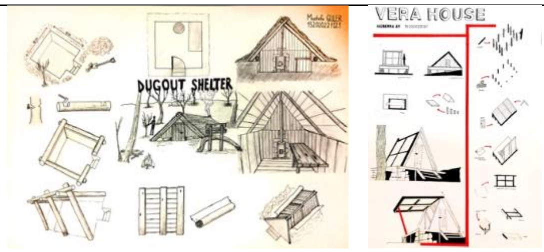
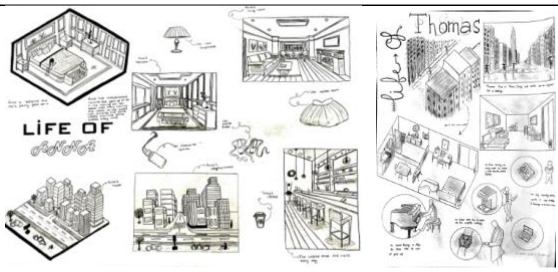
Students were encouraged to draw inspiration from their own experiences or their favorite films, television shows, and books . Once they identified the distinguishing characteristics of their character, students were required to develop a poster that visualized the information using both pictures and text. Overall, the objective of the assignments was to empower students to create both visual and verbal solutions to the given problems using architectural design tools. The utilization of verbal stimuli may lead to variations in students' performance in imaginative drawing. Specifically, verbal stimulation refers to the spoken words used to guide students in their creative design work. On the other hand, architectural sketches, as visual stimuli, served as essential resources for generating creative design ideas throughout the design process. Sketching is a highly effective means of expressing and articulating a designer's inner thoughts, as it is employed by designers to visually translate their design concepts during the conceptual design phase (Lawson, 2006). MacCrimmon and Wagner (1994) noted that stimulus-rich creative approaches have a positive impact on creativity, especially when original ideas are depleted. Based on these arguments, both sketching and verbal expressions were utilized as design tools to foster creative ideas within the design studio. The incorporation of both verbal and visual inputs into the design process was believed to yield more creative solutions, as they were considered integral components of the design thinking process.

*Divergent Thinking Task*

In this study, divergent thinking (DT) was assessed using the Wallach-Kogan Creativity Test (WKCT) (Wallach & Kogan, 1965) for two primary reasons: (1) it is a widely used divergent thinking test to evaluate the creative process of idea generation (Antonietti, 2010), and (2) its psychometric properties and suitability for Turkish samples are well-established (Sur, 2020; Togrol, 2012). We determined that the Wallach-Kogan divergent thinking tests were the most effective means of evaluating students' divergent thinking abilities, as they align with the content of the studio assignments. To ensure accuracy, the WKCT and its instructions were subjected to a back-translation process and translated into Turkish. The initial translation was completed by a researcher proficient in both English and Turkish. Subsequently, two bilingual academics familiar with creativity literature carried out the back-translation process. After incorporating their feedback and making necessary adjustments, the final translated version was approved. The WKCT (Wallach & Kogan, 1965) assesses divergent thinking and evaluates both visual and verbal information. Wallach and Kogan (1965) propose two visual subtests (ViS): Pattern Meanings and Line Meanings (interpreting abstract patterns and lines). The ViS task includes Incomplete Drawing (ID) and Pattern Meanings (PM) items, which require participants to generate ideas about what the presented drawing would look like if completed and what the presented image represents (see Table 2). Participants were instructed to generate as many ideas as possible within a given time for each ViS item."

The Wallach and Kogan (1965) DT test also encompasses three verbal subtests (VeS): Instances (e.g., list all the round objects you can think of), Alternative Uses (e.g., for a shoe). Two of these verbal items were adapted from the Wallach-Kogan Creativity Tests (WKCT). Specifically, the Instances (I) item required participants to generate instances of things that make a sound and things that are round, respectivelyIn the Alternate Uses (AU) item, participants were asked to list alternative uses for a brick and a shoe in the pre- and post-tests, respectively. The Similarities (S) item in VeS required participants to list the similarities between 'broccoli and a banana' (pre-test) and 'an apple and an orange' (post-test) (see Table 3). The selected DT tasks were based on simple verbal information and were chosen due to their high reliability and validity, as documented in previous studies (Antonietti, 2010; Aslan & Puccio, 2006; Cheung et al., 2004; Cropley & Maslany, 1969; George & Wiley, 2020; Runco & Okuda, 1988; Runco et al., 2016).

*Table 2. Examples of some student works*

| Activity | Studio Assignment | Some Students work |
|---|---|---|
| Visual Stimuli (ViS) | SW1. Abstract skyline. |  |
| | SW 2. A container composition. |  |
| Verbal Stimuli (VeS) | SW 3. In the woods. |   |
| | SW 4. Life of "X". |   |

*Scoring*

The scoring approach for SW and DT pre and post-tests was based on the fluency, flexibility, and originality scoring approach outlined by Torrance in 2006, as cited in Jamal et al. (2020). Table 3 illustrates the scoring criteria established by Torrance (2006) for DT tasks and studio works. These criteria were used to compute the scores for items in both categories. Each item in this area is worth no more than four points. This section comprises three distinct aspects. Therefore, individuals with a very high degree of inventiveness can score a maximum of 12 points. According to Torrance (1974), fluency is defined as the quantity of ideas generated. Flexibility refers to the number of different categories or techniques produced. Originality pertains to the unique or uncommon ideas generated by students. Fluency is scored based on the number of ideas students provided in the assignment. However, fluency was not only measured by the total number of ideas but also considered their relevance to the task (Ilsever, 2000). This study associates fluency with the quality of ideas, rather than relying solely on the quantity of ideas generated. Evaluators may also award points based on the quality of ideas, considering factors such as usefulness, feasibility, and originality (see Table 4). Flexibility is also linked to the number of ideas in the design work, but in this case, the category or method needs to be described. In this study, flexibility is assessed through idea clustering, where raters categorize the generated ideas into clusters based on similarities and assign scores based on the number of distinct clusters formed. This approach considers the diversity of ideas produced, not just the quantity of distinct concepts. Equally vital is the number of unique combinations of ideas developed. This not only considers the variety of ideas presented but also the ability to synthesize and integrate diverse ideas to create unique solutions. As an example of flexibility scoring, if a student provides ideas or methods for combining ideas, such as *'Anna has an indispensable routine. She wakes up at six in the morning for her ballet class every day and walks to the ballet hall,'* the participant would receive a flexibility score of two points for describing the 'indispensable routine,' including the time she wakes up and her journey to the hall. Originality relates to the uniqueness of the ideas presented in the story and is also connected to the novel aspects of the visual images created by students based on the stories they crafted. Originality, or uniqueness, is the ability to think independently and creatively (Roue, 2014). In this study, originality also encompasses the unique visual expressions within the story, including the combination of design elements from different styles in a novel way, the variety of 2D and 3D architectural representations, and the quality and unusual details of the representations. It relates to the fusion of creativity and an individual perspective in the design work (see Table 4).

For example, a participant may create unique interpretations of the story they generated, such as '...a hotel with a different spatial arrangement during the day and at night, a place where space constantly transforms: from a pyramid to a cube.' A response like 'space is constantly transforming' would receive a higher originality score compared to a common response like 'rectangular-shaped space.' As shown in Table 2, one of the student's design stories was: 'Anna is a ballerina, and she is exceptionally talented. She follows a daily routine religiously. She wakes up at six in the morning for her ballet class, and every day, she walks to the ballet hall while sipping her coffee from the same coffee mug.' The student received a fluency score of 4 since she provided more than two related ideas.

***Table 3. Testing structure, scoring, and items of pre and posttest DT tasks (This table is developed from the discussion in Wallach Kogan 1965)***

| Activity | | Description | Task instruction | Scoring |
|---|---|---|---|---|
| Visual Stimuli (ViS) | | | | Fluency: Students cannot provide ideas:0 Students can come up with one to two ideas:2 Students can come up with three or more ideas:4) Flexibility: Students are not able to provide ideas/ methods:0 Students can come up with one to two ideas/methods:2 Students can come up with three or more ideas/ methods:4) Originality: (Students do provide general ideas/ common ideas and no originality:0, Students come up with moderate unique ideas:2, Students come up with unique ideas:4 |
| | Incomplete Drawing (ID) | Guess possible meanings of the line shown in a drawing. | *Here is an unfinished drawing. Write down all the things you can think of that this drawing could be when it's finished. The more you can write, the better.* | |
| | Pattern Meanings (PM) | Figure out possible interpretations of the given pattern in a drawing. | *Interpret the line you see below. Write down everything that comes to your mind about what this line might mean. The more you can write, the better.* | |
| Verbal Stimuli (VeS) | Alternate Uses (AU) | Think of a possible use for an object | *Write down all the uses of a brick/shoe you can think of. The more you can write, the better.* | |
| | Instances (I) | Generate possible instances of a concept. | *Write down all the examples you can think of things that make sounds/ that are round. The more you can write, the better* | |

For the flexibility score, the student received 2 points as they suggested a method for connecting the ideas described in the story, such as '*...walks to the ballet hall, drinking the same coffee from the same coffee mug every time.'* As for the originality score, the student received 2 points as they came up with moderately unique ideas. However, the quality of architectural representations of the spaces was not original enough to score higher. In another example (refer to Table 2; SW 4: Life of X, picture on the right side of the row), the student received 0 points for fluency since they provided no specific details or ideas about his design story. Due to the lack of description, he also received 0 points for the flexibility score. For the originality score, the student received 2 points as they came up with moderately unique ideas. Graphical and architectural representations were better than most in the study, and the combination of design elements from different styles was unique. Current research on DT and SW tends to focus on fluency, followed by originality and flexibility. Elaboration is excluded from scoring, which refers to the details within each idea. In the flexibility scale, one of the categories that encompasses elaboration in student responses covers individually generated accompaniments.

***Table 4. Scoring Items Based on Fluency, Flexibility, and Originality (Torrance ,2006; cited in Jamal et al.,2020)***

| Creativity Domain | Score | Description |
|---|---|---|
| **Fluency** | 0 | Students cannot provide qualified ideas |
| | 2 | Students can come up with one to two related qualified ideas |
| | 4 | Students can come up with three or more related qualified ideas |
| **Flexibility** | 0 | Students are not able to provide ideas/ methods |
| | 2 | Students can come up with one to two ideas/methods |
| | 4 | Students can come up with three or more ideas/ methods |
| **Originality** | 0 | Students do not general ideas/ common ideas and no originality |
| | 2 | Students come up with moderate unique ideas |
| | 4 | Students come up with very unique ideas |

## Results

### Statistical Analysis of the SW and Pre and Post-test Scores in DT Tasks

Three raters scored the students' design works and responses to the DT items in the flexibility and originality categories, and the student's score for each item was obtained by averaging the raters' scores. Therefore, inter-rater reliability was analyzed before obtaining mean student scores. Each rater independently scored each design work generated in SW1 and SW2 for the visual stimuli score and SW3 and SW4 for the verbal stimuli score. The average of the raters' ratings was used to calculate the score for each item. Additionally, the same raters scored the pre- and post-tests for divergent thinking, including Incomplete Drawing and Pattern Meaning for the visual score (ViS) and Alternate Uses and Instances for the verbal score (VeS). Each student provided multiple qualified ideas (fluency) for DT task items, and the student works resulted in flexibility and originality scores, which are the sum of all scores for each response. Three raters assessed all student responses to DT questions and SW in terms of flexibility and originality. Before calculating the mean student scores, inter-rater reliability was examined to determine the extent to which different judges' evaluation decisions were consistent. The rater judgments for the flexibility and originality scores for the ViS and VeS items in the pre-test, post-test, and student works yielded inter-rater reliability scores that ranged between good (G) and excellent (E). (ICC[a] ranged between .835- .991) (Table 5).

***Table 5. Response-based interrater reliability results for DT tasks pre, post-test and SW***

| DT Tasks (n=40) | Flexibility | | | Originality | | |
|---|---|---|---|---|---|---|
| | ICCa | | | ICCa | | |
| | SW | Dt task | | SW | Dt task | |
| | | Pre | Post | | Pre | Post |
| Visual Stimuli (Vis) | .971 | .926 | .885 | .964 | .953 | .955 |
| Verbal Stimuli (VeS) | .916 | .835 | .844 | .961 | .963 | .991 |

*[a] The Intraclass Correlation value was calculated as a two-way random-effects model with a consistency definition. The reported value is the average measures for the three rater judgments per participant response (p<0,05).*

*[c] Agreement Classifications for Intraclass Correlation were assigned based on Koo and Li (2016) where P is Poor (<0.50), M is Moderate (0.50 - 0.75), G is Good (0.75 - 0.90) and E is Excellent (>0.90)*

Overall, the Intraclass Correlation (ICC) analyses revealed good to excellent agreement between the three rater judgments for flexibility and originality scores for the DT tasks, both pre- and post-test, and for students' works. Thus, a mean score for the SW and DT items was calculated for each student based on the three raters' judgments. The subsequent analyses of DT tasks in the pre- and post-test were based on the students' mean scores.

Student pre- and post-test scores for DT tasks and studio works were first tested for normality using the Lilliefors corrected K-S test in SPSS v.29. Mean fluency, flexibility, and originality scores rejected the null hypothesis that the data were not normally distributed. Given that the majority of the scores did not present a normal distribution, the non-parametric Wilcoxon Signed-Rank test was used to determine whether participant scores in the pre- and post-test and student works had a significant difference in their mean values. This could help test the null hypothesis: *'There is no difference in the divergent thinking ability of first-year architecture students following the first semester of the curricular intervention.'* Table 6 displays the descriptive statistics and Wilcoxon Signed-Rank test results for the fluency scores and the mean rater scores for flexibility and originality for DT pre- and post-test items for a 95% confidence interval ($p < 0.05$). The Wilcoxon Signed-Rank test results were interpreted to determine the effect of the curricular intervention on the fluency, flexibility, and originality components of first-year architecture students' divergent thinking skills.

**Fluency** refers to the quantity and quality of ideas provided by students in their responses to both student works (SW) and divergent thinking (DT) tasks in the pre- and post-tests. Pre- and post-tests, as well as student works, demonstrated statistically significant decreases in the mean fluency scores for visual (Vis) tasks. The decrease in post-test scores was not statistically significant. However, there was a statistically significant decrease in mean fluency scores for both pre- and post-test scores as well as student works ($p = 0.001$, $p < 0.001$) for Vis tasks. The results for verbal (VeS) tasks were similar to Vis. Statistically significant decreases in mean fluency scores were observed across all three tests. The decrease in pre- and post-test scores was not statistically significant, but the decrease in mean scores for both pre- and post-test scores and student works was statistically significant. ($p=.002$, $p <.001$) (see table 6).

**Flexibility** is assessed as the idea clustering by the three raters for each student. In the visual (Vis) tasks, there was a statistically significant mean increase in the pre-and post-test scores, and the result was statistically significant (p= .031). However, there was a statistically significant mean decrease between the pretest and students' works' flexibility score, but the decrease was not statistically significant. Additionally, there was a statistically significant mean decrease between the posttest and students' works score, and this decrease was statistically significant (p= .019). In the verbal (VeS) tasks, there was a statistically significant mean increase in the pre- and post-test scores, and the result was statistically significant (p<.001). Moreover, there was a statistically significant mean increase between the pretest and SW flexibility score, and this increase was statistically significant (p<.001). There was also a statistically significant mean increase between the posttest and SW flexibility score, but the increase was not statistically significant (see table 6).

**Originality** scores were calculated using the a priori categories of participant responses judged by the three raters for each student, as described in section 2.2.3. There was a statistically significant mean increase between pre- and post-test scores in Vis tasks, and the increase was statistically significant (p<.001). Similarly, there was a statistically significant increase in the mean originality score between the pretest and the students' work, and this increase was statistically significant (p= .004). In contrast, there was a statistically significant mean decrease between the pre- and post-test scores and the students' work, and this decline was statistically significant (p<.001). In VeS tasks, there was a statistically significant increase in mean scores between the pre- and post-tests, and the increase was statistically significant (p<.001). The same outcome may be seen between pre-test scores and student work (p= .011) (see table 6).

Overall, the findings indicate that students received the highest mean scores for originality on the posttest for both verbal and visual stimuli. Additionally, the mean score for flexibility in visual tasks was higher in the posttest. In addition, posttest fluency scores for verbal tasks were the highest for students. All these findings were statistically significant; hence the null hypothesis that there is no difference in the divergent thinking ability of first-year architecture students after the first semester of the curricular intervention is rejected.

***Table 6. Descriptive statistics, Wilcoxon signed-rank test results for the SW and DT tasks in pre-and post-test groups.***

| FLUENCY | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| DT Tasks *(n=40)* | Mean | | | *Wilcoxon Signed Rank* | | | | | |
| | DT | | SW | *Pre/post* | | *Pre /sw* | | *post /sw* | |
| | pre | post | | z | q | z | q | z | q |
| Visual Stimuli (Vis) | 2.98 | 2.95 | 2.08 | -344 | .731 | -3.190 | .001 | 4.005 | <.001 |
| Verbal Stimuli (VeS) | 3.08 | 3.28 | 2.45 | 1.272 | .203 | -3.166 | .002 | 4.344 | <.001 |
| FLEXIBILITY | | | | | | | | | |
| DT Tasks *(n=40)* | Mean | | | *Wilcoxon Signed Rank* | | | | | |
| | DT | | SW | *Pre/post* | | *Pre /sw* | | *post /sw* | |
| | pre | post | | z | q | z | q | z | q |
| Visual Stimuli (Vis) | 1.632 | 1.890 | 1.417 | 2.161 | .031 | -.895 | .371 | 2.349 | .019 |
| Verbal Stimuli (VeS) | 1.415 | 2.066 | 2.367 | -3.715 | <.001 | 5.080 | <.001 | -2.047 | .041 |
| ORIGINALITY | | | | | | | | | |
| DT Tasks *(n=40)* | Mean | | | *Wilcoxon Signed Rank* | | | | | |
| | DT | | SW | *Pre/post* | | *Pre /sw* | | *post /sw* | |
| | pre | post | | z | q | z | q | z | q |
| Visual Stimuli (Vis) | .8750 | 1.958 | 1.508 | 4.698 | <.001 | 2.853 | .004 | 3.477 | <.001 |
| Verbal Stimuli (VeS) | 1.107 | 2.425 | 1.692 | -3.844 | <.001 | 2.533 | .011 | 4.326 | <.001 |

**Correlations Between the Measures of DT and SW**

Given that the majority of scores did not exhibit a normal distribution, the non-parametric test statistic, the Spearman's rho test, was used to analyze the relationship between the participants' performance on the verbal and visual divergent thinking tests to establish the degree to which these two measures of DT were associated. The correlation coefficients in Table 7 indicate that the performance of students on these tests was associated in the majority of indices. The correlation analysis was performed separately for each of the test items to determine the relations between fluency, flexibility, and originality. We assessed the strength of the relationship as follows: if the absolute value of r falls between 0.5 and 0.7 ($0.5 < r < 0.70$), it means there is a moderate relationship; if $r > 0.70$, there is a strong relationship between items. If the absolute value of r is between 0.3 and 0.5 ($0.3 < r < 0.5$), there are weak correlations between items. If $r < 0.3$, we assumed that there are none or very weak correlations (Mindrila & Balentyne, 2023). In ViS_pretest, fluency was correlated with both flexibility and originality (r= .442, r= .744), and flexibility was correlated with originality (r= .419) (see Table 7). There was a weak correlation between fluency and flexibility, but the correlation between fluency and originality was strong. In VeS_pretest, only fluency moderately correlated with originality (r= .505). However, flexibility and originality, as well as fluency and flexibility, were not correlated (see Table 7). In ViS_posttest, visual fluency was correlated with flexibility (r= .465). Also, flexibility was weakly correlated with originality (r= .339). In ViS_posttest, fluency was weakly correlated with originality (r= .339), and flexibility was correlated with originality (r= .371). Accumulating evidence indicates weak correlations between flexibility and originality measures (see Table 7). In ViS_SW test, fluency moderately correlated with flexibility (r= .613). In contrast, fluency weakly correlated with originality (r= .374). However, there was no correlation between flexibility and originality. In VeS_SW test, fluency weakly correlated with flexibility (r= .485). Likewise, fluency weakly correlated with originality (r= .406). Besides, there was a weak correlation between flexibility and originality (r= .437) (see Table 7).

Overall, the findings indicate various correlations between all items. The most significant finding was the moderate to strong correlation between fluency and originality. Similarly, there were moderate correlations between fluency and flexibility. However, the correlations between flexibility and originality were weak in most of the scores. This result was consistent with the study of Dumas and Runco (2018) as fluency and originality are best conceptualized as distinct but positively correlated constructs. Correlational analysis showed that fluency was highly correlated with originality in the visual tests, whereas originality was weakly correlated with flexibility in the verbal test.

## Discussion

The present study employed a series of pre- and post-divergent thinking assessments as well as students' design projects to investigate the impact of curricular intervention on changes in divergent thinking abilities over the initial semester. The study encompassed a cohort of novice architecture students enrolled in the "Thinking in Architecture Design" course during their initial semester, with no previous experience or background in design. The intervention sought to improve the design thinking capabilities of the students by placing emphasis on the development of visual and verbal divergent thinking skills. The activities were specifically created to enhance participants' capacity to transform abstract concepts into visual depictions, foster the ability to make connections between different ideas, and cultivate spatial aptitude by honing two-dimensional visual talents. If pupils achieve the highest scores on the post-divergent test, it can be inferred that the training program has effectively enhanced their visual and linguistic abilities. Nevertheless, the post-test scores pertaining to visual stimuli fluency exhibited a notable decline in comparison to the pre-test scores, and this decline was shown to be statistically significant. On the other hand, it is noteworthy that students attained the most elevated average fluency score on the verbal posttest, and this rise exhibited statistical significance. The results indicate that students experienced an enhancement in their verbal reasoning abilities following their completion of a semester-long course titled 'Thinking in Architecture Design.' This improvement in verbal reasoning facilitated their capacity to develop a notably higher number of thoughts pertaining to relevant subjects. Furthermore, a notable and statistically significant rise was observed in the average flexibility scores of pupils after engaging in visual examinations. Nevertheless, the scores achieved by the students' effort were comparatively lower in comparison to both the pre-test and post-test scores.

*Table 7. Spearman's rho test results for the DT and SW tasks*

| | | | |
|---|---|---|---|
| PRE TEST VISUAL | | | |
| **Spearman's rho** | | **1** | **2** |
| 1. Pre_ViS_Flueny | Correlation Coefficient | | |
| | Sig. (2-tailed) | | |
| 2. Pre_ViS _Flexibility | Correlation Coefficient | .442** | |
| | Sig. (2-tailed) | .004 | |
| 3. Pre_ViS_Originality | Correlation Coefficient | .744** | .419** |
| | Sig. (2-tailed) | <.001 | .007 |
| PRE TEST VERBAL | | | |
| **Spearman's rho** | | **1** | **2** |
| 4. Pre_VeS_Fluency | Correlation Coefficient | | |
| | Sig. (2-tailed) | | |
| 5. Pre_VeS_Flexibility | Correlation Coefficient | .189 | |
| | Sig. (2-tailed) | .243 | |
| 6. Pre_VeS_Originality | Correlation Coefficient | .505** | .299 |
| | Sig. (2-tailed) | <.001 | .061 |
| POST TEST VISUAL | | | |
| **Spearman's rho** | | **1** | **2** |
| 1. Post_ViS_Flueny | Correlation Coefficient | | |
| | Sig. (2-tailed) | | |
| 2. Post_ViS_Flexibility | Correlation Coefficient | .465** | |
| | Sig. (2-tailed) | .003 | |
| 3. Post_ViS_Originality | Correlation Coefficient | .307 | .339* |
| | Sig. (2-tailed) | .054 | .032 |
| POST TEST VERBAL | | | |
| **Spearman's rho** | | **1** | **2** |
| 1. Post_VeS_Fluency | Correlation Coefficient | | |
| | Sig. (2-tailed) | | |
| 2. Post_VeS_Flexibility | Correlation Coefficient | .132 | |
| | Sig. (2-tailed) | .418 | |
| 3. Post_VeS_Originality | Correlation Coefficient | .339* | .371* |
| | Sig. (2-tailed) | .032 | .018 |
| SW VISUAL | | | |
| **Spearman's rho** | | **1** | **2** |
| 1. SW_Vis_Flueny | Correlation Coefficient | | |
| | Sig. (2-tailed) | | |
| 2. SW_Vis_ Flexibility | Correlation Coefficient | .613** | |
| | Sig. (2-tailed) | <.001 | |
| 3. SW_Vis_Originality | Correlation Coefficient | .374* | .270 |
| | Sig. (2-tailed) | .018 | .092 |
| SW VERBAL | | | |
| **Spearman's rho** | | **1** | **2** |
| 1. SW_Ver_Fluency | Correlation Coefficient | | |
| | Sig. (2-tailed) | | |
| 2. SW_Ver_ Flexibility | Correlation Coefficient | .485** | |
| | Sig. (2-tailed) | .002 | |
| 3. SW_Ver_Originality | Correlation Coefficient | .406** | .437** |
| | Sig. (2-tailed) | .009 | .005 |

*Correlation is significant at the 0.05 level (2-tailed)

** Correlation is significant at the 0.01 level (2-tailed).

The visual post-test yielded the highest mean score, suggesting that the student demonstrated proficiency in concept clustering. This proficiency was assessed by quantifying the number of distinct combinations of visual concepts generated. This result also illustrates the student's ability to combine and incorporate diverse visual elements in order to provide innovative solutions. On the other hand, the studio works produced by the students had the highest degree of verbal flexibility, exceeding the performance observed in the pre-test but not reaching the level achieved in the post-test.

These results showed that in studio work, students are more capable of idea clustering than in divergent thinking tests. This may be due to students producing verbal ideas through visual representation in the studio, whereas in DT, students generate ideas based on verbal instructions. Unexpectedly, in students' studio works, the ratio of student scores for fluency to those for flexibility was the lowest. While the students did not generate many verbal and visual ideas in the studio design works, there was a strong relationship between the concepts generated. In terms of originality scores, the assessment of the tasks produced the predicted outcome. Students achieved the highest scores in post-tests, both in visual and verbal tasks, and the results were statistically significant. The curriculum intervention had a positive effect on enhancing students' originality in terms of both visual and verbal thinking. Also, the correlation analysis indicated a strong correlation between fluency and originality, as Carroll (1993) described fluency and originality have often been proposed as core aspects of DT. Additionally, our findings supported the idea that theoretically, fluency is a prerequisite for giving an original answer (originality) (Weiss, et al., 2021). The findings indicate that fluency and originality are best characterized as different but positively associated entities, with originality exhibiting stronger construct reliability than fluency (Dumas & Dunbar, 2014).

In general, the statistical examination of student studio works and Wallach Kogan's DT pre/post-tests indicated that the post-test score for verbal stimuli fluency surpassed the visual post-test score. Furthermore, the post-test score for visual flexibility had a greater magnitude than the post-test score for verbal flexibility. The post-test evaluations for originality were found to be the highest for both the visual and verbal tasks. The results of the correlation analysis demonstrated a strong and consistent association between fluency and inventiveness. Regarding their ability to generate a greater number of ideas on interconnected subjects, pupils demonstrated higher advancement in their verbal reasoning skills compared to their visual reasoning skills. This outcome demonstrates the student's aptitude for amalgamating and incorporating a range of verbal concepts in order to generate innovative resolutions. According to Xia et al. (2021), the inclusion of design training has the potential to augment both types of creativity, with a more pronounced impact observed in the domain of divergent thinking. The curriculum intervention was designed to promote students' creativity by activating their divergent thinking capacity, with the anticipated outcome of improving their visual and linguistic aptitudes. Visual stimuli, including photographs, illustrations, and sketches, play a crucial role in facilitating students' ability to articulate their visualizations and design concepts. In addition, the presentation of visual stimuli serves to stimulate students' inclination to observe, analyze, and interpret visual information, so equipping them with the ability to understand and tackle a wide range of design challenges. On the other hand, verbal stimuli, such as scenario and story compositions, provide students with the opportunity to express and elucidate their design thinking process and reasoning. Verbal stimuli facilitate the development of critical thinking skills and the articulation of ideas.

The curriculum intervention facilitates the development of multidimensional thinking by using both visual and verbal inputs. This method empowers students to analyze design difficulties from multiple perspectives. The present study provides evidence for the effectiveness of implementing a curriculum intervention early in the training program, specifically targeting the development of divergent thinking skills. This intervention yielded significant enhancements in students' capacity to generate original ideas, both in visual and verbal formats. However, it is worth noting that the observed growth in divergent thinking abilities was more prominent among individuals with stronger verbal aptitudes. This phenomenon can be attributed mostly to the fact that the participants were first-year students who had no prior experience in graphically representing ideas. It is common for students who begin their design education straight after graduating from high school, without any prior experience in design education, to have enhanced verbal communication skills. The researchers hypothesized that students would enhance their visual skills throughout the course of the semester. This led us to the conclusion that there is a need for curriculum modification. In the realm of design initiatives, an effective strategy for enhancing accessibility involves a substantial augmentation of visual exemplifications, encompassing artworks, images, and diagrams. The objective of this strategy is to enhance students' familiarity with diverse design styles, techniques, and visual compositions, hence expanding their knowledge and understanding of the design discipline. Furthermore, it is advisable to promote the practice of sketching among students, as it facilitates the enhancement of their capacity to transform mental imagery into visual depictions. Additionally, it is imperative to underscore the essential visual components, including line, shape, color, texture, and form, alongside the principles of design, including balance, contrast, emphasis, and unity. It is imperative to offer students the chance to use these aspects and principles within the context of their own design work. Furthermore, the integration of visual analysis and research activities might be included in the curriculum. The subject matter involves the examination and interpretation of visual artifacts originating from diverse cultural backgrounds, historical epochs, or design fields. This academic pursuit facilitates students in acquiring a more profound comprehension of visual communication and its relationship to cultural milieu.

It should be noted that the sample size of design works in this preliminary study, consisting of 160 works collected from 40 students, represents a substantial portion of the students participating in the 'Thinking in Architecture Design' course. However, it is important to acknowledge that this limited sample size may be perceived as a potential limitation of the study. This study is perceived as an initial endeavor towards conducting a broader and more extensive study, which would involve collecting data from a larger cohort of students enrolled in diverse academic disciplines.

## Conclusion

The primary objective of this study was to examine the influence of a curriculum intervention on the divergent thinking abilities of first-year design studio students. The research employed two distinct assessment tools: the students' design studio tasks and Wallach Kogan's tests of divergent thinking. The results indicated that the curriculum intervention, which emphasized the development of divergent thinking skills during the first semester of training, led to improvements in students' visual and verbal divergent thinking skills. These improvements were particularly evident in terms of originality, while gains in fluency and flexibility in idea generation were comparatively modest. The findings of our study offer valuable recommendations. Firstly, divergent thinking should be incorporated into design training programs to encourage the production of more original design ideas. Secondly, teaching divergent thinking as an integral part of the design training program, informed by research, would be ideal. Additionally, educators should foster divergent thinking at early stages of education. Consequently, future studies on creativity should prioritize the examination of diverse thinking among students.

## References

Antonietti, A. A. (2010). Representing the Mind: A Collection of Instruments to Assess Naive Psychological Conceptions. *Procedia - Social and Behavioral Sciences, 2*(2), 4732-4736.

Aslan, E., & Puccio, G. (2006). Developing and Testing a Turkish Version of Torrance's Tests of Creative Thinking: A Study of Adults. *The Journal of Creative Behavior, 40*(3), 163-177. DOI: 10.1002/j.2162-6057.2006.tb01271.x.

Carroll, J. B. (1993). *Human cognitive abilities: A survey of factor–analytic studies.* Cambridge University Press.: Cambridge.

Cheung, P. C., & Lau, S. (2010). Gender differences in the creativity of Hong Kong school children: comparison by using the new electronic Wallach- Kogan creativity tests. *Creat. Res. J., 22*, 194–199. doi: 10.1080/10400419.2010. 481522.

Cheung, P. C., Lau, S., Chan, D. W., & Wu, W. Y. (2004). Creative Potential of School Children in Hong Kong: Norms of the Wallach-Kogan Creativity Tests and Their Implications. *Creativity Research Journal, 16*(1), 69-78 .

Coleman, E., Shealy, T., Grohs, J., & Godwin, A. (2020). Design thinking among first-year and senior engineering students: a cross-sectional, national study measuring perceived ability. *J. Eng. Educ., 109*, 72–87. doi: 10.1002/jee.20298.

Cropley, J., & Maslany, G. (1969). Reliability And Factorial Validity Of The Wallach-Kogan Creativity Tests. *Br. J. Psychol., 60*(3), 395-398.

Demirkan, H., & Afacan, Y. (2012). Assessing creativity in design education: Analysis of creativity factors in the first-year design studio. *Des Stud., 33*, 262–278. https://doi.org/10.1080/10400410409534549.

Doron, E. (2016). Short Term Intervention Model for Enhancing Divergent Thinking among School Aged Children. *Creativity Research Journal, 28*(3), 372–378. doi:10.1080/10400419.2016.1195616.

Dumas, D., & Dunbar, K. N. (2014). Understanding Fluency and Originality: A latent variable perspective. *Thinking Skills and Creativity, 14*, 56–67.

Dumas, D., & Runco, M. (2018). Objectively Scoring Divergent Thinking Tests for Originality: A Re-Analysis and Extension. *Creativity Research Journal, 30*(4), 466-468 https://doi.org/10.1080/10400419.2018.1544.

Erwin, A., Tran, K., & Koutstaal, W. (2022). Evaluating the predictive validity of four divergent thinking tasks for the originality of design product ideation. *PLoS ONE, 17*(3), e0265116. https://doi. org/10.1371/journal.pone.0265116.

George, T., & Wiley, J. (2020). Need something different? Here's what's been done: Effects of examples and task instructions on creative idea generation. *Mem. Cogn., 48*, 226–243. https://doi.org/10.3758/s13421-019-01005-4.

Guilford, J. (1967). *The nature of human intelligence.* New York: McGraw-Hill.

Guilford, J. P. (1950). Creativity. *American Psychologist, 5*, 444–454.

Guilford, J. P. (1956). The Structure of Intellect. *Psychological Bulletin, 53*(4), 267-293.

Hassan, D. (2016). Divergent thinking techniques discrepancy and functional creativity: Comparative study of structural and procedural techniques in architectural design. *Ain Shams Eng J.*, http://dx.doi.org/10.1016/j.asej.2016.10.002.

Ilsever, Y. (2000). *A New Method of Scoring Torrance `s Test of Creativity.* Columbia: A Master Thesis in Arts. University of British Columbia. https://open.library.ubc.ca/media/download/pdf/831/1.0107133/1.

Jamal, S., Ibrahim, N., Halim, N., & Alias, I. (2020). A preliminary study on the level of creativity among chemistry students in district of Melaka Tengah. *Journal of Critical Reviews, 7*(16), 752-761. doi: 10.31838/jcr.07.16.88

Koo, T. K., & Li, M. Y. (2016). A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. *Journal of chiropractic medicine, 15*(2), 155–163. https://doi.org/10.1016/j.jcm.2016.02.012.

Lawson, B. (2006). *How Designers Think: The Design Process Demysti.* Oxford: Elsevier/Architectural.

Lemons, G. (2011). Diverse Perspectives of Creativity Testing: Controversial Issues When Used for Inclusion Into Gifted Programs. *Journal for the Education of the Gifted, 34*(5), 742–772. https://doi.org/10.1177/0162353211417221.

Lissitz, R. W., & Willhoft, J. L. (1985). A Methodological Study of the Torrance Tests of Creativity. *Journal of Educational Measurement*, 1-11 .

MacCrimmon, K. R., & Wagner, C. (1994). Stimulating Ideas through Creativity Software. *Management Science, 40*(11), 1514-1532. https://doi.org/10.1287/mnsc.40.11.1514.

Mayahi, M., & Mazhari, M. (2023). Articles in Press: Divergent Thinking: a Tool for Assessing Students' Creativity in Architectural Design . *Space Ontology International Journal*, 10.22094/SOIJ.2023.1961624.1500.

Mindrila, D., & Balentyne, P. (2023). *Scatterplots and Correlation.* Retrieved February, 27, 2023 from Westga: https://www.westga.edu/academics/research/vrc/assets/docs/scatterplots_and_correlation_notes.pdf

Mumford, M. D., Vessey, W. B., & Barrett, J. D. (2008). Commentary: Measuring Divergent Thinking: Is There Really One Solution to the Problem? *Psychology of Aesthetics, Creativity, and the Arts, 2*(2), 86–88.

Palmiero, M., Fusi, G., Crepaldi, M., Borsa, V., & Rusconi, M. (2022). Divergent thinking and the core executive functions: a state-of-the-art review. *Cognitive Processing, 23,* , 341–366. https://doi.org/10.1007/s10339-022-01091-4.

Peak, S. (2003). *Investigations of The Validity of Divergent Thinking Tests, Doctoral Dissertation.* Korea,: Seoul National University of Education.

Raef, M. A., Masoudineja, M., & Vasigh, B. (2022). Experiences in Architecture Creativity Education in Iranian Universities with an Emphasis on the Effects of Divergent and Convergent Thinking (Case Study: Faculty of Art and Architecture, Iran University of Science and Technology (IUST). *Creative city design, 5*(4), 58-69.

Rao, H., Puranam, P., & Singh, J. (2021). Does design thinking training increase creativity? Results from a field experiment with middle-school students. *Innovation Organ. Manage*, 1–18. doi: 10.1080/14479338.2021. .

Reiter-Palmon, R., Forthmann, B., & Barbot, B. S. (2019). Divergent thinking tests: A review and systematic framework. *Psychology of Aesthetics, Creativity, and the Arts, 13*(2), 144–152.https://doi.org/10.1037/aca0000227.

Richards, R. (1976). A Comparison of Selected Guilford and Wallach-Kogan Creative Thinking Tests in Conjunction with Measures of Intelligence. *Third Quarter, 10*(3), 151-164.
Roue, L. C. (2014.). Gender-Based Differences in School-Aged Chidren's Divergent Thinking. *International Journal of Cognitive Research in Science, Engineering and Education, 2*(2), https://www.ijcrsee.com/index.php/ijcrsee/article/view/133/602.
Runco, A., Abdulla, M., Paek, S., Al-Jasim, F., & Alsuwaidi, H. (2016). Which Test of Divergent Thinking Is Best? *Creativity. Theories – Research – Applications, 3*(1), 4-18.
Runco, M. A. (2008). Commentary: Divergent thinking is not synonymous with creativity. *Psychology of Aesthetics, Creativity, and the Arts, 2*(2), 93–96. https://doi.org/10.1037/1931-3896.2.2.93.
Runco, M. A., & Okuda, S. M. (1988). Problem Discovery, Divergent Thinking, and the Creative Process. *Journal of Youth and Adolescence, 17*(3), 211-219.
Silvia, P. J. (2008). Creativity and intelligence revisited: A reanalysis of Wallach and Kogan (1965). *Creativity Research Journal, 20*, 34-39.
Silvia, P. J., Martin, C., & Nusbaum, E. C. (2009). A snapshot of creativity: Evaluating a quick and simple method for assessing divergent thinking. *Thinking Skills and Creativity, 4*, 79–85.
Silvia, P. J., Winterstein, B. P., Willse, J. T., Baron, C. M., Cram, J. T., & Hess, K. I. (2008). Assessing Creativity With Divergent Thinking Tasks: Exploring the Reliability and Validity of New Subjective Scoring Methods. *Psychology of Aesthetics, Creativity, and the Arts, 2*(2), 86–88.
Sopher, H. (2020). Analysing Divergent -Convergent Activities in the Architectural Studio with the aid of the 'Knowledge Construction Activities Model`. *Sixth International Conference on Design Creativity* (pp. 302-310, 10.35199/ICDC.2). Oulu, Finland: ICDC.
Sowden, P. T., Clements, L., Redlich, C., & Lewis, C. (2015). Improvisation facilitates divergent thinking and creativity: Realising a benefit of primary school arts education. *Psychology of Aesthetics Creativity and the Arts, 9*(2), 128-138 DOI: 10.1037/aca0000018.
Sun, M., Wang, M., & Wegerif, R. (2020). Effects of divergent thinking training on students' scientific creativity: The impact of individual creative potential and domain knowledge, *Thinking Skills and Creativity, 37*(2), 100682.https://doi.org/10.1016/j.tsc.2020.100682.
Togrol, A. Y. (2012). Studies of the Turkish form of the Test for Creative Thinking-Drawing Production. *Creative Education, 3*(8), 1326-1331.
Torrance, E. P. (1972). *Torrance tests of creative thinking—directions manual and scoring guide—figural test, booklet. A*. Lexington: Personnel Pres. Inc.
Torrance, E. P. (1974). *Torrance tests of creative thinking.* Lexington, MA: Personnel Press.
Torrance, E. P. (2006). *Torrance Test of Creative Thinking.* Ben-senville: Scholastic Testing Service.
Tran, K. N., Kudrowitz, B., & Koutstaal, W. (2020). Fostering creative minds: what predicts and boosts design competence in the classroom? *Int. J. Technol. Des. Educ.*, 1–32. doi: 10.1007/s10798-020-09598-7.
van de Kamp, M.-T., Admiraal, W., van Drie, J., & Rijlaarsdam, G. (2015). Enhancing divergent thinking in visual arts education: Effects of explicit instruction of meta-cognition. *British Journal of Educational Psychology, 85*(1), 47-58. https://doi.org/10.1111/bjep.12061.
Wallach, M. A. (1970). Creativity. In P. M. (Ed.), *Carmichael's handbook of child psychology* (pp. 1211–1272). New York: Wiley.
Wallach, M. A., & Kogan, N. (1965). *Modes of thinking in young children: A study of the creativity-intelligence distinction.* New York: Holt: Rinehart and Winston.

Weiss, S., Steger, D., Kaur, Y., Hildebrandt, A., Schroeders, U., & Wilhelm, O. (2021). On the Trail of Creativity: Dimensionality of Divergent Thinking and its Relation with Cognitive Abilities, Personality, and Insight. *European Journal of Personality, 35*(3), 291–314. https://doi.org/10.1002/per.2288.

Xia, T., Kang, M., Chen, M., J., O., & Hu, F. (2021). Design Training and Creativity: Students Develop Stronger Divergent but Not Convergent Thinking. *Front. Psychol., 12*, 695002. doi: 10.3389/fpsyg.2021.695002.

Zeng, L., Proctor, R. W., & Salvendy, G. (2011). Can Traditional Divergent Thinking Tests Be Trusted in Measuring and Predicting Real-World Creativity? *Creativity Research Journal, 23*(1), 24-37.doi: 10.1080/10400419.2011.545713.