# Innovating Industrial Design Curriculum in a Knowledge-Based, Participatory and Digital Era

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## Abstract

This article discusses three years' research (2012-2014) on design education towards a 2016 undergraduate industrial design curriculum launch. It contributes a pathway for conservative courses towards design culture transformation and filling gaps between them and leading breakthrough education exemplars. The course proposes a collective knowledge creation model through social constructivism and constructionism that recognises its place in time and history and allows customisation to individual upbringing. It catches up with a profession transformed beyond a digital Bauhaus manifesto that joined and revaluated physical and digital artefacts as per their environment, quality of experiences, intelligence, networks and relations. Data and findings supported pedagogy redefinition from master-apprentice and teacher-centred skill transmission models to heutagogy and paragogy. The new approach required habitus change from a traditional goods-centred discipline to human-centred focus, critical design and making, design heuristics, CDIO (conceiving, designing, implementing, operating) and STEAM (science, technology, arts, mathematics) frameworks. Participants empathetically contextualised, problem framed and solved by crossing boundaries between disciplines, institutions, industries, students' background and society. Research and practice promoted new forms of industrial design creation happening in physical and digital coexisting spaces of being. Course units evolved around an e-curriculum component working as a digital spine. Curriculum progressed from standard top-down transmission to sociotechnical and organisational networking, industry collaboration, international design studio and Design Factory model-like projects. In doing so, it became a foundation for future physical-digital industrial design artefacts, human computer interaction, machine learning, hacker culture systems, shared information, free open-source software and hardware development within a 4.0 industrial revolution.

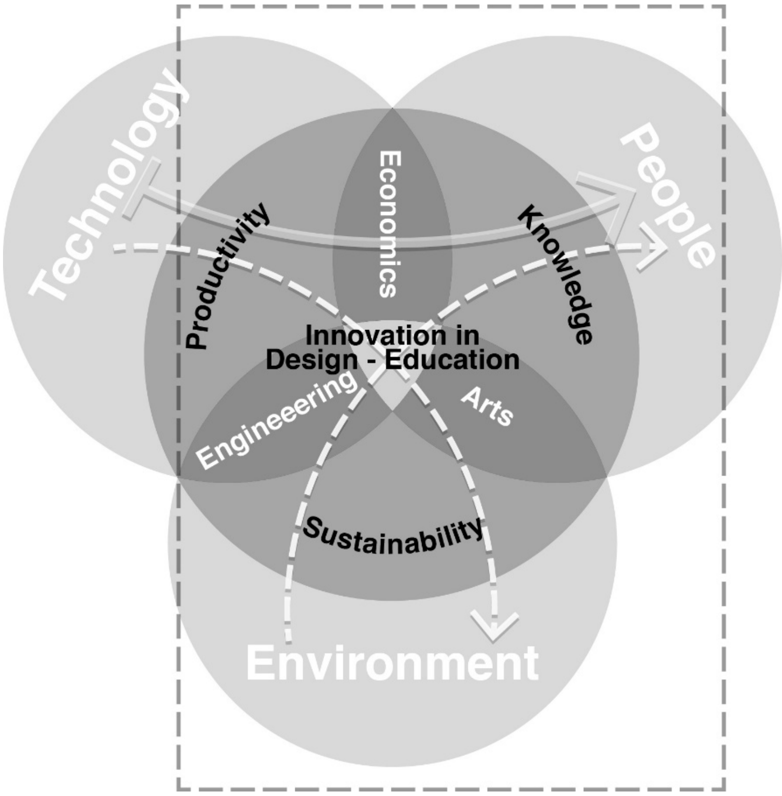
## Key words

cultural-historical activity theory, constructivism, constructionism, CDIO, design education, STEAM

## Introduction

Experts propose design has cultural significance beyond wealth creation and situate designers as change agents, culture generators, and reference point for policy makers and intellectuals of the future (Hustwit, Beshenkovsky, Geissbuhler, & Dunne, 2009). These claims evoke Bauhaus artist-designers' aspiration to lead society into social wellbeing from a century ago. Yet, today many designers lack the intellectual and commercial preparation to lead business, politics and social change. Numerous industrial design educations are still linked to specialised assembly and manufacturing, while higher education relies on massification of teaching and strong preconditioning of outcomes for its survival. We live in a knowledge-based economy, decades after a digital Bauhaus manifesto that transferred design meaning from mass production to experience and knowledge creation. Timely, this article discusses an undergraduate design degree makeover (2012-2014) which focuses on an individual and collective knowledge production model through social constructivism and constructionism. It redefines design artefacts as tangible and intangible knowledge-based capital that realigns cultural, historical and spatial setting to address relationships between environment, people and technology. Design heuristics help overcome the physical-digital divide with empathy, contextualised human-centred and experiential design, and crossing boundaries between disciplines and participants. Social constructivism defines cognitive processes as knowledge construction by learners through their own distinctive system of knowing, making and modelling. Constructionism means the physical, digital and social process by which those creations materialise through continuous conversation, interaction, critical design and making.

Educational institutions play a pivotal role in the past and future of social development, whereas curriculum imparts discipline rules and prepare students for the profession. Course culture is thus determined within the push-pull between environment, people and technology that challenges established conventions (Figure 1). In particular, design courses' agency depends on innovation while still suffering unresolved dilemmas. A definitional crisis polarises programs between the extremes of artist-designer (inspired creative genius) and engineer-designer (scientific calculation resolving complicated problems). There is also a gap between well-funded benchmarks and design education that frequently struggles economically because of normative constraints and increasing



pressure towards massification of higher education. New, cheaper information and communication technologies (ICT) further redefine human relations, their space and time dimensions (e.g. face-to-face, mediated, distributed, augmented) while also replacing traditional professions. Lastly, academia is experiencing rising demands to develop competencies not available in standard design education (e.g. collective, creative, empathic). Fittingly, this research aims to answer: *how can an industrial design curriculum enable participants' knowledge construction to develop a design-driven innovation culture in a digital era?* Supporting this, there are questions of how to:

A. Update curriculum when design artefacts are no longer physical only?
B. Diminish uncertainty and stimulate constructive collaboration?
C. Bridge the physical-digital divide while transforming participants from technology consumers to active cultural producers and mediators for social benefit?

***Figure 1: Environment, people and technology push-pull challenging design education. Reprinted from Author, 18 January 2012, Vision for Industrial Design Course: Presentation to Directors of Academics Program Panel, Unpublished internal document .***

## Method

This paper firstly uses epistemology to define and contextualise the challenge of industrial design in the current knowledge-based, participatory and digital era. Particularly, research on theories of knowledge that look into what constitute a design artefact, its historical context and effects on pedagogy. Cultural-historical activity theory was found to suit the process of course reformulation best. The paper then looks at the second step in this project that focused on a curriculum development that recognised education and technology benchmarks, and developed a new course with collaborative and interventionist research approach to re-address design education for current times:

## Results

## Epistemology

## The Design Artefact

Design artefacts have experienced semantic shifts alongside social and technological changes. Industrial design has primarily persuaded society through physical artefacts. These were understood as *objects* (entities with purpose), as opposed to *things* (natural entities independent from human intention or no longer serving function). Artefacts resulted from applying practical skill (Latin *arte*) to make well and good (*facere*) 'man-made' statements (*factum*). Social and material culture experts assumed them as tangible, ready-made and matters-of-fact (empirically measured) material properties capable of influencing human behaviour. Yet, a design artefact is not just an artefact. It is also a technical object. (Greek *techne:* crafted, manufactured, systematic). Concepts of truth, belief and socio-environmental connections affected how they carried knowledge.

Originally, the English word for design came from old Greek past tense (*eschein*) for *to have* or *possess something.* The embedded meaning was about loss of possession which required artefact representation to prevent humans from forgetting (Terzidis, 2007). Its Latin root (*de*: out, *signare*: drawing a sign) meant marking to preserve mental images. Latour (2004); (2008) argues that design became exhausted last century as it turned into superficial stylistic representations (*relooking*) as veneers of fashion taste. He proposes a constructivist approach *redrawing* two disconnected narratives together. One of emancipation, detachment, modernisation, progress and mastery, and the other completely different of attachment, precaution entanglement, dependence and care in favour of *redesigning* effective nature and society ecosystems (e.g. climate change, equity, globalisation). Current problems are too multifaceted to condense as material matters-of-fact and input-output productivity. Design artefacts must transform from image representation to purposely constructed things capable of addressing matters-of-concern (undefined with relative implications) by appropriate processes that solve ambiguous and complex challenges.

This curative design strength can help us re-evaluate artefacts beyond *possession* (consumption) and *relooking* (fashion) to *re-seeing* and *seeing-through* solutions for humanity and nature as acts of iterative meaning construction. Consequentially, design is better defined with active verb expressions (e.g. making, modelling, testing) with non-finite properties in process of continuous development and interpretation. As with Dutch description (*ontwerp*), projected modelling inquires the present to improve future realities through research, collaborative and evolutionary improvements. Design education can futureproof discipline and students by teaching design artefacts which are epistemic instruments. They are characteristically fluid, non-static permeable and porous to their context, environment and users. A four knowledge construction periods timeline (Figure 2) assists understanding design artefacts' past and future incarnations as:

1. **Product-Production:** Craftsmanship representing inspiration on constructed (a priori) knowledge.
2. **Process-Method:** Industrial and material applied research for forming and mass production.
3. **People-Participation:** Intricate challenges represented by people as consumers (e.g. behaviour, cognition), and the start of the electronic era (e.g. information, productivity, technology).
4. Stages 1-3 are characterised by linear, simple and complicated problem-solving needing passive or restricted user operation to complete them (e.g. cars, chairs).
5. **Place-Time-Practice:** Design artefacts as projects figuring out complexity and users (e.g. choices, decision-making, experience) through practice and forward (posteriori) knowledge construction in undefined environments. This requires active *redesigning* of artefacts as presentative platforms needing user intervention to generate and regenerate design (e.g. apps, coding, artificial entities). Characteristically, it involves co-creative and empirical habits based on empathy, discovery, participatory action research (PAR), modelling, and customised forecasting and production. Since people can now design their own artefacts while identity and knowledge are easily reconfigurable through physical-digital

materiality, spaces, time narratives, networks, cyber-culture, 4.0 industrial revolution's automation, generative design and artificial intelligence.

## Historical Context

Most industrial designers are Bauhauslers because of heritage. Bauhaus (1919-1933) merged art and technology to democratise industrialisation. Gropius' manifesto denounced artists and designers as glorified craftsmen-decorators, and aesthetes who were isolated from their socio-historical environment (Gropius, 1919). He opposed *pedagogy's* (Greek *paida*: children, *gogo*: to lead) master-apprentice model that guided passive students via transmission and task replication (Herbart, 1806; Majorek, 1998). Bauhaus was influenced by other movements (e.g. Deutscher Werkbund, Novembergrouppe), intellectuals (e.g. Weber, Frankfurt School of Social Sciences) and Dewey's re-imagining of learning as problem-based, hands-on, pragmatic education (Bergdoll & Dickerman, 2009; Dewey, 1902; Maciuika, 2005).

A 6-year constructivist artist-designer syllabus consolidated industrial design past crafts and draughtsmanship into higher art by making it inseparable from research and social implication (Armengaud, 1853; Betts, 2004). Learners' iterative trial-and-error experimentation heuristics (Greek *heureskein*), transformative dialogue, prototyping and testing started from foundational analysis to nature, science (e.g. manufacturing, mathematics, geometry), comparative studies, and final specialisation. Unembellished design artefacts were the archetypal integration of research science and visual arts, artist and machine aesthetics (Dondis, 1973; Saletnik & Schuldenfrei, 2013). Ground-breaking, Bauhaus-visible influence gave designers moral value with worth beyond productivity. Social change resulted from artefacts' immediacy as "it is impossible to procure knowledge without the use of objects which impress the mind" (Dewey, 1975). However, Bauhaus did not translate well elsewhere.

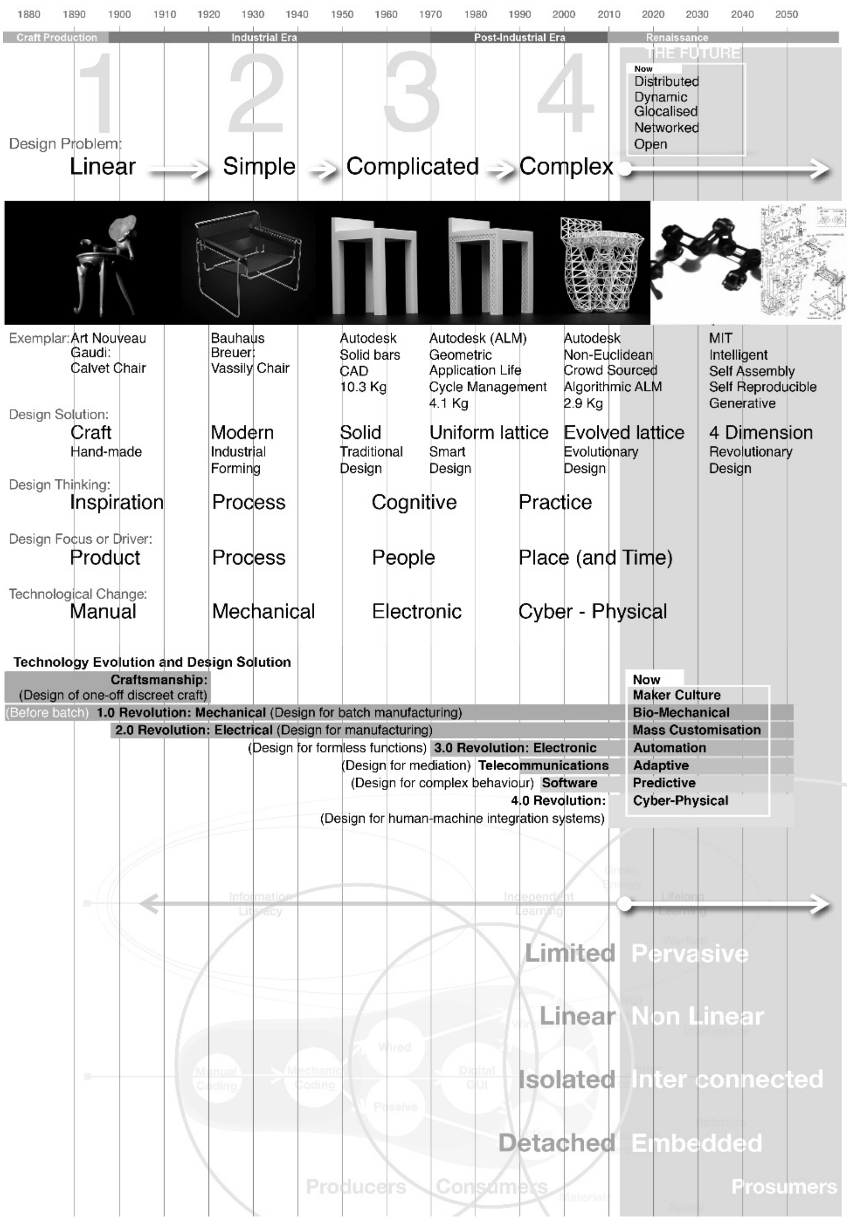



***Figure 2: Industrial design's four knowledge construction eras. Reprinted from Author, 27 October 2014, Industrial Design Curriculum 2016: New Vision and Imperatives for the New Normal of Innovation and its Education, Unpublished internal document*.**

Mostly in post-war United States (U.S.) and United Kingdom (U.K.), many designers, educators and intellectuals tried to engineer society. As an example, the International Style kept Bauhaus functionalism minus its social significance. Asemantic modernism rejected ordinary human, social and geographical interests. Government, corporate and education projects used design as instrument of control that befell users unable to connect with it. Experts predicated rationalistic methods would automatically make the world better by stringent procedures. Thus, design followed collected computing data, logical deduction and mathematical optimisation models (Miller & Tilley, 1984). Simon advocated artificial intelligence would do any work a man did within 20 years (Simon, 1969), while Habermas critiqued the notion of social engineering replaced the old with a new Enlightenment promising to solve all problems (Habermas, 2012). People became dissocialised consumers at the mercy of financial markets. Designers and their artefacts became mythical high-tech commodities under technologists' control that permeated society and institutions (e.g. academia, law, sciences) with self-supporting processes empty of meaning (Lyotard, 1984; Zuidervaart, 1993). Adorno pointed to increasing fetishism the further meaning was lost in the push-pull among production and malfunctioning people's social mechanisms (e.g. arts, communications, culture experts, education) needed to figure out their alienation (Horkheimer, Adorno, & Noeri, 2002).

Elsewhere, in Germany and Northern Europe, design went beyond artist-designer and engineer-designer ideologies to set the foundation for human-centred design (HCD) and education thereafter. The HfG Ulm School (1953-1968) proposed design as an everyday life discipline assisting national reconstruction. Idiosyncratic research methods converted consumers into user-participants who integrated technology and culture through design (Olt Aicher, 1919; 1994; Krippendorff, 2008; Maldonado, 1958). Ulm's research-driven and project-based program built on humanism, pragmatism, semiotics and Frankfurt School principles. The 4-year course had a collaborative first-year introducing students to 4 interdisciplinary pillars: industrial design, building, visual communication and information. Gorman (2003) explained that practice and theory focused on cultural theory, chemistry, mathematics, methodology (e.g. logic, permutations, topology), perception, physics, presentation (e.g. drawing, drafting, language, typography), sociology, visual methods (2 and 3-dimensional experimentation), and workshop (e.g. metal, photography, wood). Ulm argued that information technologies transformed artefacts' material qualities and users into abstract data with a new concept of industrial duplication. Representation became more important as technocrats' decision-making and modelling perfection succeeded only if human subjective interference was eliminated (Maldonado, 1972). Yet, design was neither science nor engineering or artistic intuition. Instead, it was defined by artefacts and users' activity, interaction and values. This freed design artefacts from material-oriented views conceiving that industrial design was to solid materials as graphic design was to paper (Bonsiepe, 2010; Oswald, 2012).

After the 1970s, following phenomenological analysis of style, methodology and industrial production, design thinkers proposed design as a third creative culture in-between the two traditional ones of humanities-social sciences and science-technology (Archer, Baynes, & Roberts, 1992, 2005). Cross (1982, 2001, 2007) categorised design research as either by, for or through design. Others argued designers are sense-making beings rather than problem solvers only (Dorst, 1997; Dorst & Dijkhuis, 1995; Gedenryd, 1998). However, Ehn (1998) was the one who indicated academia had fallen behind from Bauhaus and HfG Ulm bequest. His Digital Bauhaus Manifesto offered a multidisciplinary, reflective and participatory course at Sweden's Malmö University. Students merged arts, crafts, design and technology. Design expanded to interaction, participatory design (PD) and human computer interaction (HCI) in an experience economy. Design embraced a digital revolution that transgressed material space, time, culture divisions and hard (e.g. materials, manufacturing) and soft (e.g. coding, ethics, management) technologies. Artefacts, environments, participants and time no longer followed linear patterns. They also became virtual and fluid. Consumers as users were present, mediated, distributed, co-present or augmented through participative creation of interactive narratives.

Two decades on, education is slowly adapting to experience design while users are knowledge workers already living a knowledge-based and innovation-driven economy.

They work on non-routine problem solving and independently produce new knowledge and ways to transmit it as portable capital assets regardless of their position in a globalised market (Drucker, 1999, 2011). Fittingly, Bremner and Rodgers (2013) said design is in a 40-year crisis as a "discipline without a discipline". Concerns are that professional strengths are hijacked by non-designers (Cruickshank, 2014; Lockwood, 2010; Martin, 2007; D. H. Pink, 2006). Business, local authorities and marketing use design methods as common sense, non-ideological and depoliticised technics (e.g. IDEO's Design Thinking). Thus, non-designers may sacrifice design's innovation if applying its methods as replicable templates that are indifferent to problems of complexity, contexts and users (Jacob, 2013). Design can again solve the disconnect in society by *re-seeing* the industrial (Latin *industria*: diligence, manufacturing) in design with a new meaning for manufacturing (Latin *manu:* human intervention, *facture:* making) and wellbeing. Success cannot be measured by production efficiency and fashion as before. Instead, it should be by defining outcomes at the other end. Precisely at the moment of design artefact *instantiation* when users negotiate design artefact effectiveness. This notion expands designers' mediation to any field with similar application of its principles, theory, or classes of objects. It helps to establish new dialectics between humans and artefacts, and among artefacts. This is a welcome diversification as industrial design based on material production is changing. Today's high-tech design, computer power and hard technology may cost as little as US$5.00 by 2032 (Stross, 2014).

## Pedagogy

Design education agency depends on pedagogy that can reflect the productivity shift from conspicuous consumption to globalised design-driven digitalisation, experience and knowledge. With good timing, Fallan (2010) credited industrial design with building a discourse increasingly independent from art and based on context and artefact-user interaction. However, the education business is hazardous. Institutions often suffer contradictions that still affect pedagogy with the legacies of the last century. Funding constraints increase pressure to massify education to loss of critical thinking (Liem & Sigurjonsson, 2014). Pope (2016) states that curriculum is used as political tool that organises, codes, mediates and administers power. Others denounce a slippery slope with a neoliberal agenda that uses technocratic measures as a Trojan horse, where managerialism forces teachers into predefined learning outcomes and instrumentalised education away from quality and critical reflection (Gleeson, 2013). Logically, universities constantly invest in infrastructure to improve their visible clout and maintain claims of excellence. Also, ICTs are often sought after to maximise performance, as they are cheaper than face-to-face and project-based learning. Yet, large and costly physical projects run in opposite directions to digital knowledge flow costs that are becoming portable, transmittable and free for users within and outside those institutions. Technological disruption also brings new players intending to control communication, education and news on strength of social networking and algorithmic formulae (e.g. Facebook, Google).

Admittedly, Gropius' departure from the Beaux-Arts academy had a first-year intake more prepared and a course longer than ours. Yet, Bauhaus underscored the significance of active construction of knowledge through heuristics. It ran against trends that maintained the asemantic and preconditioned status quo through modernism and post-modernism.

19th century *pedagogy* and 20th century adult education (*andragogy*), behaviourism and Bloom's taxonomy, all pursued the approach of efficient skill transfer as instruction that pre-empted behaviour before it had occurred (Alberto & Troutman, 2012; Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956; Herbart, 1806; Kapp, 1833; Knowles, 1980; Skinner, 1974; Watson, 1913). Prescriptive environments greatly disregarded participants' critical (Greek *kritikos*: discernment) state of mind. In this century, technology may add to that tendency against learning if Web 1.0 (data broadcasting), 2.0 (personalised information), 3.0 (peer-centred, semantic web) and 4.0 (open, linked, intelligent cyber-physical generation) evolution is thought as solved with ICT decontextualised from changes to ideology, users and environment.

Recent pedagogical models explain learning for our times as decentralised, experiential, transmediatic, peer-centred and crossing institutional and disciplinary boundaries indifferent to physical and digital dimensions (Table 1). Self-determined discovery (*heutagogy*) and peer-to-peer generative learning (*paragogy*) can extend Bauhaus' and Ulm's constructivist and critical theory framework. They encourage learners to query users and environment, improve and influence the social, historical, and ideological structures that produce and constrain them (Corneli & Danoff, 2011; Corneli, Danoff, Pierce, Ricaurte, & Macdonald, 2015; Hase & Kenyon, 2013; Kenyon & Hase, 2001). Fittingly, (2012) epistemology schema helped curriculum development as a query for changing the status quo through physical and digital artefacts and activities (Figure 3). Based on a metaphor of centres, he showed that technical simplification, top-down and fundamental universal control on design do not help in making sense of and solving current complex, distributed, dynamic, networked and open challenges, because:

- *Abandoned-centre* frameworks show typical industrial age syllabus that imparts skills as single discipline 'true particular'. Academics risk siloism within walls of technology, specialisation, lack of shared understanding, content and purpose.
- *Soft-centre* models represent belief on 'universal' generalisable truths that cross over discipline boundaries as with cross-, inter- and multi-disciplinary relations. However, stronger disciplines may take over younger ones. As with design, more powerful and evolved histories (e.g. arts, science, social sciences) have affected it because of a lack of an independent discourse.
- *Hard-centre* models propose individual discipline principles depend on a hard core containing fundamental universal laws (e.g. École des Beaux-Arts aesthetics, Bloom's taxonomy determinism).
- *Liquid-centre* structures show best suited as designers must be flexible and open to dialogue. Participants' beliefs and facts conform 'real particulars' that inform customisation, innovation, problem framing and solving, systemic perspective, and transdisciplinary collaboration.

| Learning Attribute | Pedagogy (Herbart 1806) | Andragogy (Kapp 1833, Knowles 1980) | Heutagogy (Kenyon and Hase 2001, 2013) | Paragogy (Cornelli and Danoff 2012, 2015) |
|---|---|---|---|---|
| Etymology (Greek | *Peda*: chidren; *gogy*: I lead | *Andr*: man; *agogus*: leader of | *heureskein*: discover; *gogy*: I lead | *Para*: generation, *gogy*: I lead |
| Definition | Teacher directed children Instruction | Adult self-directed learning | Self-determined learning | Peer to peer learning |
| Motivation | Internal factors: Instruction | Internal factors: Instruction | External factors: Meta-learning | External factors: Meta-learning |
| Control | Institution | Institution | Learner | Peer-centered |
| Cause | Trade education | Further education | Wayfinding | Sharing, mixing |
| Model | Transmission | Transmission | Transformative | Transformative |
| Key query | What to learn | What to learn | How to learn | How to learn |
| Learning | Passive | Operational | Collaborative | Networked |
| Learner Role | Enters education not knowing | Enters education ready to learn | Learner-centered autodidacticism | Learner-centered skilled agent |
| Teacher Role | Teacher-centered (content, process) | Guide-mediator (content, process) | Moderator (process over content) | Influencer (content, process, practice) |
| Student Dependence | Dependent on teacher and strict curriculum | Independent as curriculum is optional | Interdependent among learner, teacher, users | Peers dependent (equals but different) |
| Focus | Skill transfer | Upskilling | Experimentation | Knowledge flow |
| Curriculum | Prescriptive | Discretionary | Critical thinking-making | Generative |
| Context | Centralized | Centralized | Decentralized | Decentralized |
| Classroom | Classroom based training | Supplementary to objectives | Studio, research workshop | Hyper-connected |
| Narrative | Discipline specific | Discipline specific | Transmediatic | Transmediatic |
| Resources | Teacher's classical student conditioning | Experience and pragmatic | Non-linear problem framing and solving | Crowd-sourcing and distributed |
| Outcome | Degree, employment | Performance, competition | Self-efficiency, effective innovation | Knowledge curation, redesign |

***Table 1: Pedagogy models in relation to design education and technology***

*Note.* Based and adapted from Corneli and Danoff (2011); Corneli et al. (2015); Hase and Kenyon (2013); Herbart (1806); Kapp (1833); Kenyon and Hase (2001); Knowles (1980).

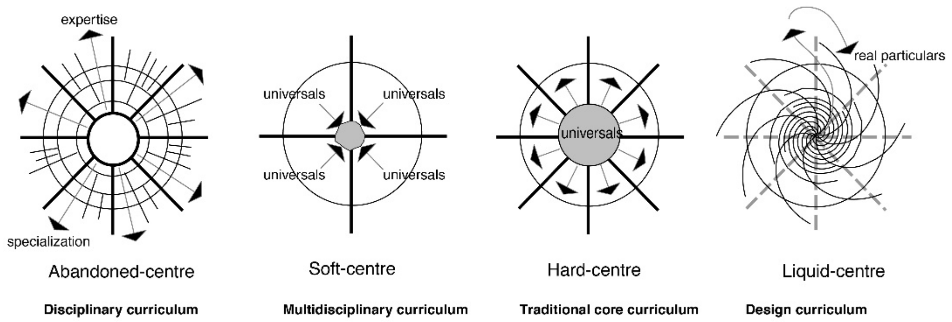



***Figure 3: Design learning epistemology. Reprinted from Nelson, H. G. (2012). The Design Way: Intentional Change in an Unpredictable World (Second edition. ed.). Cambridge, Massachusetts: MIT Press, Copyright © 2012 Harold G. Nelson and Erik Stolterman.***

## 1 Cultural and Historical Activity Theory

As per several authors, including Engeström (1987); (1990, 2001, 2009a, 2009b, 2014; 2010); Kaptelinin (2013); Khayyat (2016); Sannino (2011); Yamagata-Lynch (2010), cultural-historical activity theory (CHAT) intends to understand the relationship between humans' minds (e.g. thinking, emotion) and actions (what they do). In particular, this research focused on third-generation (3GCHAT) and fourth-generation (4GCHAT) theory. A first-generation activity theory (AT) attempted to provide a dialectical materialist analysis of mediating artefacts that revealed human mind and behaviour. These were cultural artefacts that broke with traditional explanation of reality as Cartesian dualisms (e.g. mind versus matter, individual versus rigid social structure). Society could not be explained away from individuals' agency in the production of knowledge and use of artefacts. Similarly, individuals were no longer isolated from their cultural means. Psychological and social stimulus and response depended on the mediation of those artefacts. This relationship was represented with a triangular model having mediating tools and signs (M) in the top vertex above a subject (S) and an object (O) that occupied left and right horizontal vertices below respectively. A second-generation theory (CHAT) made a case of reconstructing human activity's culture and history as indispensable to understand learning. That was achieved by expanding AT unit of analysis from individual action to a collective system defined by rules, community and division of labour. However, CHAT had methodological shortcomings presented by its focus on singular activities and a descriptive nature in relation to qualitative research in western countries.

Gaining momentum since late 1980s, 3GCHAT fitted the project as it proposed the researcher should take a participatory and interventionist role in participants' activity while avoiding being predictive and pre-emptive of their creative contribution. Collaborative process and analysis aimed to find and ask the right questions to figure out complex real-life problems rather than providing ready-made answers. 3GCHAT upgrade of AT recognised that mediating artefacts and objects "exhibit multiplicity. They represent multiple perspectives, voices, dialogues, contexts and boundary crossings" (Spinuzzi, 2015). CHAT also expanded from a single unit of analysis that focused on individual psychology to encompass the means capable of bringing about organisational change. This was a needed revaluation of the theory. Education and psychology mainly had not embraced the dialectical and materialistic conception of humanity as creator and transformer of culture.

3GCHAT multiple activity relations were investigated based on an activity system analysis (ASA) that built from a minimum expression of two-activity systems modelled as shown in Figure 4. Research depended on cultural-historical background, context, inner relations and contradictions between stages of production, consumption, exchange and distribution. Accordingly, specific circumstances affected humans' and non-humans participants' roles and degrees of influence within the nodes of that model from subject (observer), to object (person or thing observed or acted upon), mediating instrument (e.g. technology, tool), mediating activity, theory and practice (e.g. critical thinking process), power play (e.g. rules of management), community (e.g. socio-cultural capital), division of labour (e.g. people's allocated tasks), and outcomes as artefacts that were either physical, digital or abstract (e.g. products, services, theoretical models, behaviour).

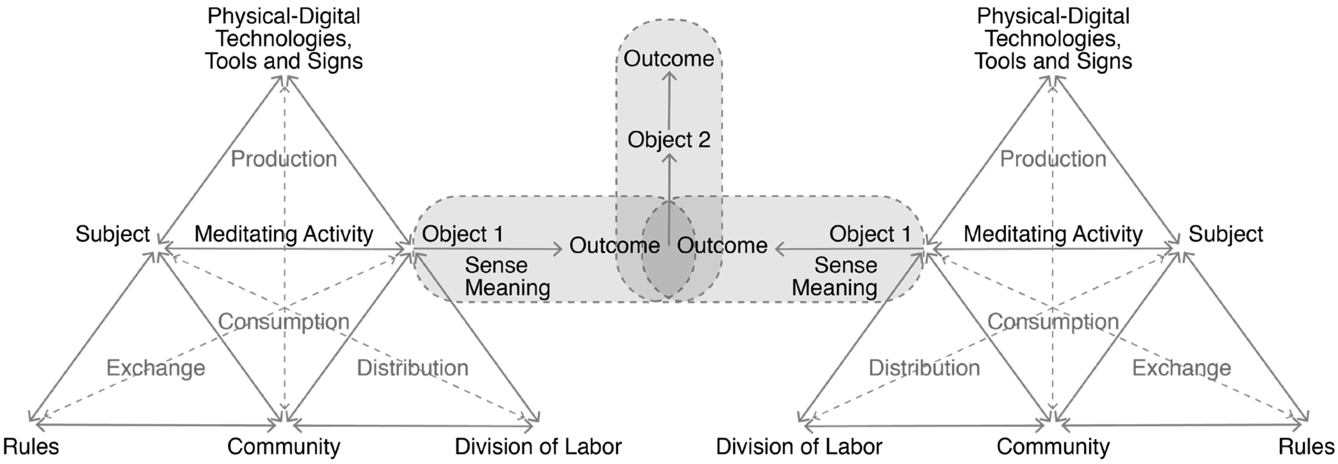



***Figure 4: 3GCHAT model. Adapted from Engeström, Yrjö, 2014, Learning by Expanding: Cambridge University Press, Copyright © Yrjö Engeström 1987, 2015.***

ASA captured change as it ensued instead of the way it was hypothesised. Researchers recognised CHAT's origin in psychology but revealed its concepts of activity and artefact had inter- and transdisciplinary nature and problems that could only be resolved by including other research fields. Design research in education and innovation was one such contributor since it focuses on the making and use of artefacts while crossing boundaries among disciplines, media and networks. Border crossing has already subverted traditional business talk about users and students as objects. Many professionals still design for an illusionary user that is assumed but not consulted. Similarly, universities tend to model education around an archetype of student (from Latin *studere*: applying oneself to, painstaking application) who individually acquires and is transmitted skills. Following (Krippendorff, 2005), there is a great need to include both users and students as active stakeholders in the process of design and education today. Recent trends have promoted the building of communities of practice (Wenger, 1998) and co-working in flexible and open workplaces. However, the former has proven ahistorical and reliant heavily on a sole craft or profession, and conditional on a single skill or authority emanating from a leader. The latter frequently results in a *working alone together* habit that is not conducing to border crossing and true collaboration (Spinuzzi, 2012).

Better yet, 4GCHAT upgrades communities of practice to a concept of *collaborative communities* particular to knowledge-intensive firms and learning that is cultural, contextual and historically based. It recognises that users and students bring with them contingencies not normally considered by old teaching models which prefer to simplify business and make it efficient. Engeström (2008); (2013) has named these contingencies *runaway objects*, referring to contested cultural and historical objects that have been traditionally disregarded and hidden. Runaway objects are not under any one discipline's control. They normally start as marginally small, with peculiar individual issues having a chance to grow if not considered. Their expanding influence generates opposition and controversy that can disrupt, and potentially emancipate, design and education by creating radical instances for development and wellbeing.

4GCHAT also upgrades co-working to *co-configuration* as a new scenario of dialogical knowledge production where designers, users and learners become guides, negotiators and boundary-spanners (individuals linking internal innovation systems). Co-configuration promotes sociotechnical networks that produce new knowledge, customer-intelligent artefacts, products and services that learn and adapt to individual experiences since humans endlessly create new objects, meanings and have changing needs. This is a new landscape of knowledge construction moving away from central authority, status or hierarchy to value-rationality that holds designers, users, lecturers and learners as peers of each other. Yet, co-configuration is frail. It depends on the time a project takes and the space it is held (e.g. closed, open, fixed, flexible, co-present, tele-present) before new teams form with another goal. Effective collaborative communities arise from co-creating values woven as *knots* in a grid of runaway objects, and contradictions that affect single discipline skills and participants (e.g. academics, students) in similar way to *mycorrhizae-like* activities (symbiotic association between fungus and roots that helps production of nutrients, growth, and underground communication among plants and trees).

3G and 4G CHAT were significant recognising that essential tinkering of design and learning (gaining knowledge by making) cannot be measured bi-dimensionally (length of schooling, technical skill width) anymore. Evaluation needed to be three-dimensional by including time and space as variables helping to discover participants' *knots* of relations, *runaway objects* and *mycorrhizae-like* activities that affect knowledge construction and learning (Figure 5). The time variable would assist contextualising a participatory curriculum evolution while the space variable would describe participants' depth of critical development. Active students as learners (old English *leornian:* to get knowledge, be cultivated) had to progressively tinker into deeper spaces of knowledge over time to form a *continuum* of artefacts (e.g. abstract, digital, physical, discipline and language related) and activities without preconditioned boundary. Hence, design learning had to its earlier cultural and historical base represented by phases of product-production, process-method and people-participation to recent complexity involving place-time-practice. Yet, those artefacts were not to represent general, global, and value-neutral knowledge as in the natural and social sciences. Counter to traditional disciplines, design developed artefacts for particular moments, purpose and people (Kuutti, 2005).

## Curriculum Development

### Curriculum and Infrastructure Benchmark

A new gameplay required a move from assumed knowledge and material-oriented descriptions to a curriculum based on informed knowledge. Course success depended on identifiable signatures that enable significance and attractive reputation. Students had to learn more (e.g. economy, environmental issues, politics, social sciences) and discover modern critical thinking, in order to shift away from technology's oppression to empowerment of people (Norman, 2010, 2015). Yet, widespread differences positioned design and education as contested concepts that needed contextualisation (Gallie, 1955; Tucci & Peters, 2015). The traditional definitions of industrial design by the Industrial Design Society of America (IDSA) and the International Council of Societies of Industrial Design (ICSID) as appearance and manufacturing of three-dimensional machine-made products, were especially telling. ICSID kept its 1957 definition until its 2017 relaunch as World Design Organisation (WDO). It then updated its definition of industrial design to the "strategic problem-solving process that drives innovation, builds business success, and leads to a better quality of life through innovative products, systems, services,

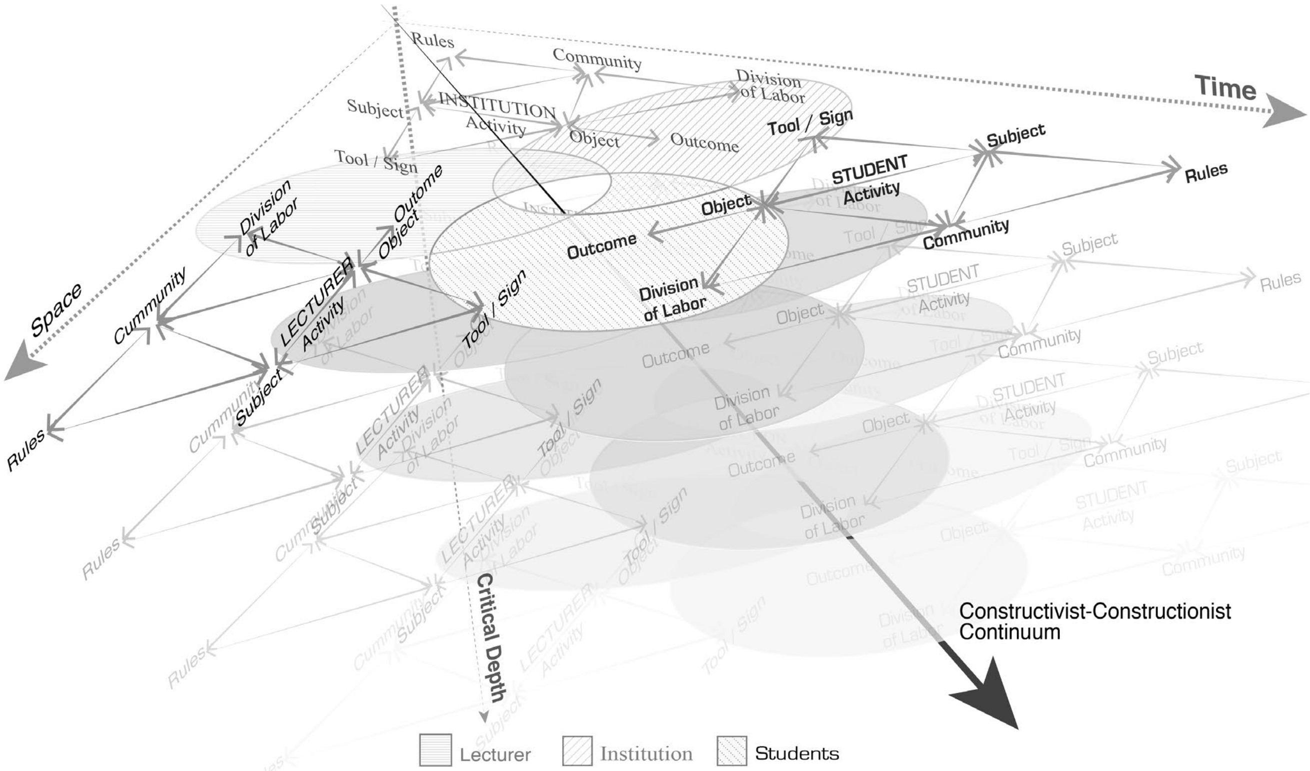



***Figure 5: ASA course space-time paradigm. Reprinted from Author, 27 October 2014, Industrial Design Curriculum 2016: New Vision and Imperative, Unpublished internal document.***

and experiences" (WDO, 2017a). This description intends to embrace extreme descriptions such as: "to entertain us, to make sure we are comfortable and warm, safe and wealthy" (Seno, 2010); "service design which does not stick to the product form but wisely used in all public fields" (Shenzhen Industrial Design Association); "primarily about better user experience" (Dublin Institute of Technology); or as the Strate School of Design, Paris, claim: "industrial design is dead, long live design! We define ourselves as a post-industrial design school' …. 'Today, the issues are no longer industrial ones. They are societal challenges; it is about' …. 'life quality'" (WDO, 2017b).

European benchmarks were seen as leading international breakthrough education exemplars to follow. Still, it was inappropriate to transplant ready-made solutions given that European redesignings were built on unique points in culture and history time ago. Instead, attention went to U.S. because of its influence on industrialisation in Australia and the U.K. Both had a similar Anglo-Celtic base to the Australian context and their *redesigning* happened more recently. Data showed a shift away from industrial assembly and manufacturing. The U.S. Bureau of Labor Statistics (2017a) described industrial design as "art, business, and engineering to make products that people use every day. Industrial designers focus on the user experience in creating style and function for a particular gadget or appliance". As per Table 2, that definitional change has parallel effects on the skills sought by the industry now. Traditional skills seem to trend down and are less determinant for gaining jobs in the last decade (PayScale, 2017).

The U.S. case is similar to changes in U.K. 20 years earlier, when the latter needed new competencies for business and innovation due to globalisation (Figure 6). Tony Blair's government established a Creative Industries Task Force (CITF) in 1997. It included industrial design in an array of economic activities to generate knowledge and exploit creativity as the ultimate economic asset. Leading U.K. thinkers coined new terms such as the 'creative economy' that placed capital value on knowledge workers' novel imagination instead of traditional forms of capital, such as property, labour, and input-output production (Howkings, 2001). In addition, the Design Council U.K. promoted their Creative Britain agenda (Cox, 2005; Design Council, 2005). Echoing that change, Deloitte elaborated recently a four-competencies model with skills needed by designers today, as shown in Figure 7 (Deloitte, 2015).

Ranking carried out for this research showed 96 U.S. universities and colleges contained some kind of design content. Specifically, 64 had specific industrial design courses (30 undergraduate, 30 undergraduate and postgraduate mix, 4 postgraduates only). U.S. Design courses are accredited by the National Association of Schools of Art and Design. Yet, not all schools adhere to it, nor disclose information about them. Only 40 were IDSA registered (Industrial Designers Society of America, 2014). Curricula, teaching approaches and outcomes highlighted divisions between engineering and artistic perspectives that suffered a shake-up a decade ago. Subsequently, several design schools redefined their role and agency. Before 2007-2008 Global Financial Crisis (GFC), many programs failed students for not gaining real design process education. Often, engineering programs claimed to be design ones. Students learned design thinking which lacked insights from cultural, aesthetic and form intelligence. Most graduate portfolios showed 3D CAD and model-making skills missing creativity (Amit, 2010).

U.S. education post-GFC started to change, filling the gap between traditional education and market expectations, and to address complex and yet undefined social and technology challenges. Surveys from 2009 onwards demonstrated a significant shift in education and industry concerns. As per grey highlighting in Tables 3 and 4, approximately the same design courses remained in the top 10 list in the last decade after cross-referencing data among Deans, Department Heads and experts' views from 2,237 firms and organisations. Signature programs led by cooperation, participatory design, integrative design that extended onto HCI and service design, well rounded and trans-disciplinary programs, design maturity, advocacy, technical strengths, flexible curriculum, learner and user-based design, strategy, research and methods, theory, industry ties and sustainable design practice. Their approach also positioned them among leading programs at international level (Design Future Council, 2009, 2013, 2014, 2016; Graphiq, 2017; PayScale, 2017; Q. S. Top Universities, 2016, 2017; U.S. Bureau of Labor Statistics, 2017b; U.S. Department of Labor, 2017).

*Table 2: U.S. skills trends affecting salaries for industrial designers as per PayScale (2017)*

| Trend | Skills | Trend | Skills |
|---|---|---|---|
| ▲ 12% | Project Management | ▼ 0% | Adobe Photoshop |
| ▲ 11% | Engineering Design | ▼ 1% | SolidWorks |
| ▲ 4% | Concepts and Standards | ▼ 2% | 3D Rendering |
| ▲ 3% | Computer Aided Design (CAD) | ▼ 3% | Graphic Design |
| ▲ 2% | Design | ▼ 3% | Adobe Illustrator |
| ▲ 2% | Product Development | ▼ 3% | AutoDesk |
| | | ▼ 3% | 3D Printing |
| | | ▼ 5% | AutoCAD |

***Note.* Reprinted from PayScale, 2017, Industrial Designer Salary, by PayScale Human Capital, retrieved from https://www.payscale.com/research/US/Job=Industrial_Designer/Salary, Copyright © 2018 PayScale, Inc.**

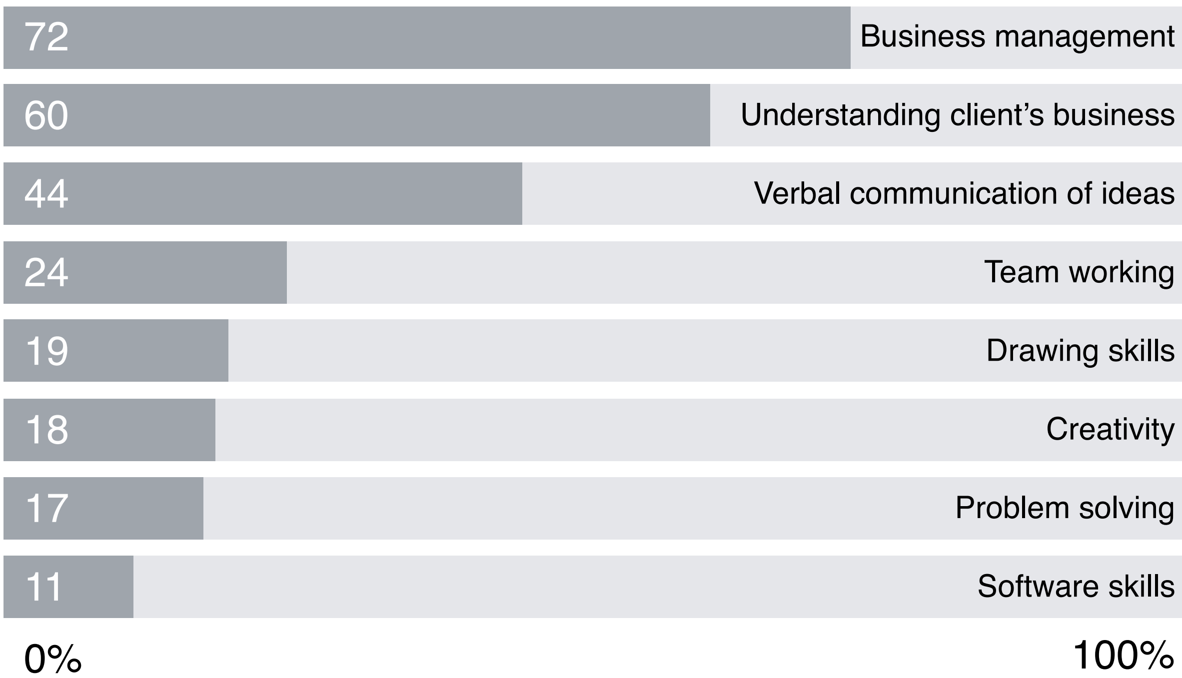



***Figure 6: U.K. skills designers lack the most. Reprinted from Design Council, UK, 2005, The Business of Design: Design Industry Research in 2005, retrieved from www.designcouncil.org.uk, Copyright © 2005 Creative Commons.***

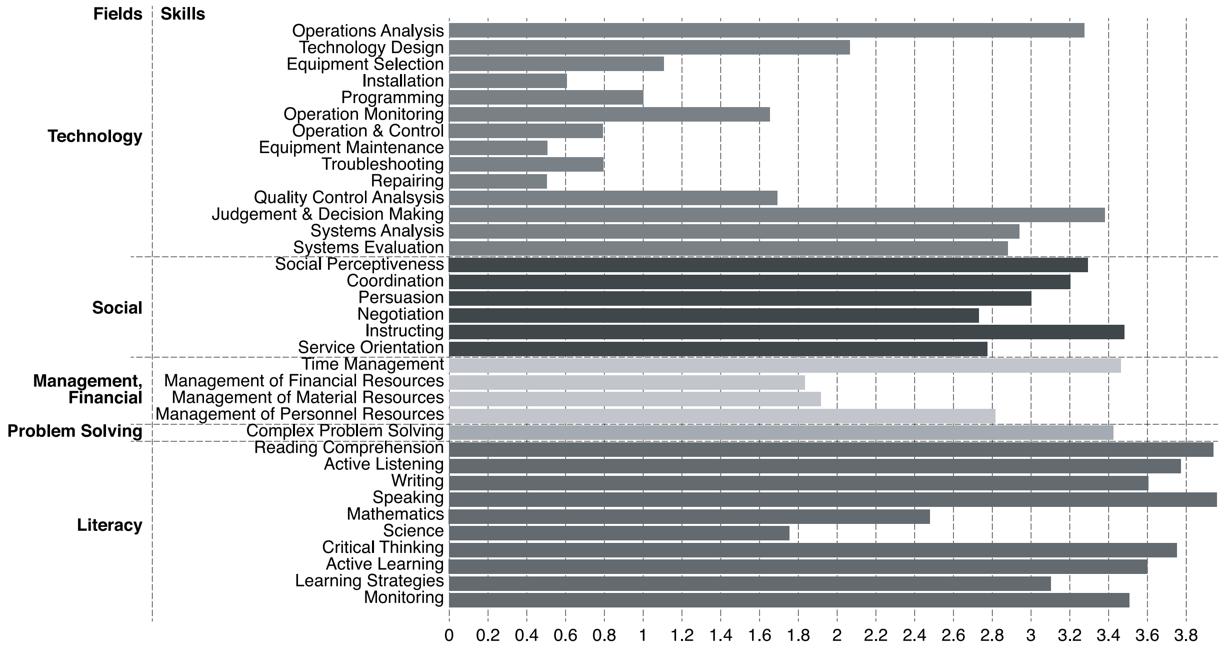



***Figure 7: Critical skills for jobs employing industrial designers. Reprinted from Deloitte, 2015, Industrial & Product Design, Data USA, retrieved from [https://datausa.io/profile/cip/500404/](https://datausa.io/profile/cip/500404/), Copyright © GNU Affero General Public License v3.0 (GPLv3).***

Two design schools often in the top 2 positions in the last decade were significant in understanding the shift needed for modern design education. Rhodes Island School of Design (RISD) was awarded the 2011 Forbes Best School after changing their traditional and analogue course to incorporate digitalisation, *critical making* (hands-on object-oriented process that merges physical and digital exploration and promotes conceptualisation and shared acts of making instead of focusing on evocative objects), and STEAM (science, technology, engineering, arts and design, mathematics) in 6 years. STEAM upgraded STEM (science, technology, engineering, mathematics) that had difficulty translating skill into creative innovation (Guyotte, Sochacka, Costantino, Walther, & Kellam, 2014; 2015; Maeda, 2012; Somerson & Hermano, 2013).

The Carnegie Mellon program defined the 21st century need to transition towards a sustainable society within a globally interconnected and interdependent world. A multi-year change process transformed academic culture based on a new pedagogical framework of design iterations and making of artefacts spanning among the built, social and natural worlds. Three design tracks were offered: product, communications, and environments. The latter recognised that the previous two now happen together in physical and digital spaces and ecologies. Consequentially, students had the choice of customising pathways that focused on a continuum of design approaches: service, social innovation and transition. They were encouraged to shift focus from products to quality of interaction and experiences, social, cultural and economic problems, and to research and speculate long term vision to reformulate lifestyles and society's infrastructure (policies, energy resources, transport, manufacturing, economy and food, healthcare, and education systems), develop new mindsets, theories and ways for designing and change (Irwin, 2015; Irwin, Tonkinwise, & Kossoff, 2013).

The comparison of U.S design programs overall revealed a complex array of offerings and setups; nevertheless, official rankings were not always complete. On the one hand, leading programs were neither purely engineering nor art focused. Instead, they intended to build design as a solid innovation-driven discipline with transdisciplinary collaboration, user-centred, participatory and meaningful research. On the other, several traditional programs ranked high and attracted many students based on institutional reputation. Data, as per Figure 8, indicated that U.S. online real-time job market prospects shown to the public still profiled conventional pathways for the profession (PayScale, 2017).

There was an oversupply of U.S. graduates for an industry that was ahead of education, but that was still not catching up with the effects of globalisation and technology. 2015 surveys showed 1,819 new graduates that year, with expectations of graduate growth of 2% per year in an industry of 38,400 industrial designers, and only 800 further jobs offers by 2024. Course fees also affected students' access, performance and job prospects depending those were private or public (e.g. education, institutional assets investment per student). Ideal students-to-teacher ratio showed as 12:1 to 15:1 for project-based learning and critical thinking. Private courses had an average of 13:1 with a minimum of 3:1. All ratios in the public-sector courses were too high, averaging at 18:1 with margins between 16:1 and 27:1. Internationally, four courses ranked 10 bests, eleven in the 11-50, and eight among the 51-100 ranking. U.K. Quacquarelli Symonds showed leading U.S. and European courses now compete against upcoming Asian offerings; this is a sign that education, industry and innovation are no longer the patrimony of first world countries.

International benchmarks revealed the need to transform mindsets and to close skill gaps in an Australian context that is characteristically conservative but that needs to compete in a globalised market. It is noteworthy that the Australian Bureau of Statistics (ABS) classified industrial design as "technical commerce" together with fashion and jewellery in 2006 (ANZCO 232312). The ABS still embeds it with mass and batch production saying designers "plan, design, develop and document industrial, commercial or consumer products for manufacture with particular emphasis on ergonomic factors, marketing and manufacturability" (Australian Bureau of Statistics, 2015). Recently, the proposal of industrial design within the creative industries followed overseas trends. However, education and professional practice need to reshape to achieve that goal. Professional and state bodies have not changed much in the last 20 years.

***Table 3: 2017 U.S. industrial design courses and majors ranking (a)***

| | Name | SC | QS | QS Ranking | QS5 | DI D UG | DI D G | DI Q | SC R | Accept (%) | Grad (%) | S2T Ratio | Pub | Priv (NFP) | Priv (FP) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Massachusetts Institute of Technology (MIT) | | * | 2 | 5+ | | | | 3 | 8.3 | 93 | 3 | | * | |
| 2 | School of Art Institute of Chicago (SAIC) | | * | 7 | | | | BM | NR | 66.5 | 54 | 9 | | * | |
| 3 | Yale University | | * | 8 | 5+ | | 3 | | 2 | NR | NR | 12 | | | * |
| 4 | California Institute of the Arts (CalArts) | | * | 12 | | | | | NR | 24.9 | 57 | 7 | | * | |
| 5 | New York University (NYU) | | * | 22 | | | | | 101 | 32.1 | 84 | 10 | | * | |
| 6 | University of California, Los Angeles (UCLA) | | * | 13 | | | | | 33 | 17.3 | 90 | 16 | * | | |
| 7 | Columbia University, New York | | * | 24 | 5+ | | | | 3 | 6.6 | 94 | 25 | | | * |
| 8 | School of Visual Arts New York (SVA) | | * | 25 | | | | | NR | 75.3 | 65 | 9 | | | * |
| 9 | Princeton University | | * | 34 | 5+ | | 15 | | 13 | 7 | 97 | 11 | | * | * |
| 10 | University of Southern California | | * | 46 | | | | | 11 | 20 | 50 | 29 | | | * |
| 11 | University of Chicago | | * | 49 | 5+ | | | | 15 | 8.4 | 88 | 6 | | | * |
| 12 | Brown University | | * | 51-100 | | | | | 17 | 9.5 | 84 | 9 | | | * |
| 13 | Cornell University | | * | 51-100 | 5+ | | | | 20 | 15.1 | 93 | 9 | | | * |
| 14 | Cranbrook Academy of Art, Bloomfield Hills, MI | | * | 51-100 | | | | M | NR | NR | 5.7 | NR | | | |
| 15 | Maryland Institute College of Art | | * | 51-100 | | | | | NR | 47.4 | 73 | 9 | | | * |
| 16 | Savannah College of Art and Design | | * | 51-100 | | | | | NR | 69.9 | 68 | 20 | | | * |
| 17 | University of California, San Diego (UCSD) | | * | 51-100 | | | | | 58 | 33.7 | 86 | 19 | * | | |
| 18 | University of Michigan | | * | 51-100 | 5+ | | | BM | 36 | 26.3 | 90 | 12 | * | | |
| 19 | University of Pennsylvania | | * | 51-100 | 5+ | | | M | 9 | 10.2 | 96 | 6 | | | * |
| 20 | Virginia Commonwealth University | | * | 51-100 | | | | | NR | 79 | 57 | 17 | * | | |
| 21 | Illinois Institute of Technology, Chicago | | * | | | | 3 | M | 150 | 52.7 | 63 | 13 | | | * |
| 22 | Art Institute of Colorado, Denver | | * | | | | | B | NR | | 35 | 18 | | | * |
| 23 | Southern Illinois University Carbondale | | * | | | | | B | NR | 80.6 | 44 | 21 | * | | |
| 24 | University of Notre Dame Indiana | | * | | | | | BM | 18 | 19.8 | 95 | 10 | | | * |
| 25 | Kansas State University Ames | | * | | | | | BM | NR | 94.9 | 60 | 19 | * | | |
| 26 | Kendall College of Art and Design, Chicago, IL | | * | | | | | B | NR | 74.4 | 28 | 8 | | | * |
| 27 | Northern Michigan University Marquette | | * | | | | | B | NR | 69.9 | 48 | 21 | * | | |
| 28 | Wayne State University Detroit | | * | | | | | BM | NR | 79.9 | 32 | 16 | * | | |
| 29 | New Jersey Institute of Technology | | * | | | | | B | 310 | 60.8 | 58 | 17 | * | | |
| 30 | Stanford University Stanford, California | * | | 8 | 5+ | | | | 4 | 5.1 | 95 | 10 | | * | |
| 31 | Georgia Institute of Technology Atlanta, GA | * | | | | 5 | | BM | 48 | 33.4 | 79 | 18 | * | | |
| 32 | Carnegie Mellon University Pittsburgh, Pennsylvania | * | | 13 | | 3 | 1 | BM | 52 | 24.6 | 87 | 10 | | * | |
| 33 | University of Illinois, Urbana-Champaign Champaign, IL | * | | 51-100 | | | | BM | 70 | 59.0 | 84 | 19 | * | | |
| 34 | University of Washington-Seattle Campus Seattle, DC | * | | 51-100 | | | | BM | 86 | 55.2 | 81 | 18 | * | | |
| 35 | Brigham Young University-Provo Provo, UT | * | | | | | | B | 94 | 47.0 | 77 | 18 | | * | |
| 36 | Ohio State University-Main Campus Columbus, OH | * | | 51-100 | 5+ | | | BM | 102 | 53.0 | 82 | 18 | * | | |
| 37 | Syracuse University Syracuse, NY | * | | | | 5 | | | 126 | 53.2 | 82 | 16 | | * | |
| 38 | Purdue University-Main Campus West Lafayette, IN | * | | | | | | BM | 129 | 59.3 | 70 | 12 | * | | |
| 39 | Clemson University Clemson SC | * | | | | | | | 131 | 51.5 | 82 | 16 | * | | |
| 40 | Virginia Polytechnic Institute and State Uni. Blacksburg | * | | | | | | B | 142 | 72.6 | 83 | 16 | * | | |
| 41 | North Carolina State University at Raleigh, NC | * | | | | | | BDM | 146 | 51.6 | 71 | 16 | * | | |
| 42 | Iowa State University Ames, Iowa | * | | | | | | B | 214 | 86.9 | 71 | 19 | * | | |
| 43 | Rhode Island School of Design Providence, Rhode Island | * | | 3 | | 2 | 3 | BM | 215 | 32.6 | 86 | 10 | | * | |
| 44 | University of San Francisco San Francisco, California | * | | | | | | | 235 | 60.1 | 67 | 14 | | * | |
| 45 | Auburn University Auburn University, Alabama | * | | | | | | BM | 254 | 83.5 | 68 | 17 | * | | |
| 46 | University of Utah Salt Lake City, Utah | * | | | | | | B | 261 | 81.4 | 59 | 17 | | * | |
| 47 | Cedarville University Cedarville, Ohio | * | | | | | | | 277 | 74.5 | 72 | 13 | | * | |
| 48 | Arizona State University-Tempe Tempe, Arizona | * | | 51-100 | | | | M | 280 | 84.3 | 58 | 22 | | * | |
| 49 | University of Illinois at Chicago, Illinois | * | | | | | | BM | 312 | 74.5 | 58 | 17 | * | | |
| 50 | Rochester Institute of Technology Rochester, New York | * | | | | | | BM | 323 | 57.5 | 63 | 13 | | * | |
| 51 | California State University-Long Beach Long Beach, CA | * | | | | | | BM | 330 | 35.5 | 57 | 25 | * | | |
| 52 | Appalachian State University Boone, NC | * | | | | | | B | 359 | 62.7 | 66 | 16 | * | | |
| 53 | Drexel University Philadelphia, PA | * | | | | | | B | 367 | 76.0 | 65 | 10 | | * | |
| 54 | University of Houston, TX | * | | | | | | BM | 393 | 63.0 | 46 | 22 | * | | |
| 55 | Western Washington University Bellingham, WA | * | | | | | | B | 400 | 84.6 | 67 | 19 | * | | |
| 56 | University of Kansas Lawrence, KS | * | | | | | | BM | 404 | 91.4 | 64 | 17 | * | | |
| 57 | University of Cincinnati-Main Campus Cincinnati, OH | * | | 51-100 | | 1 | 5 | B | 444 | 75.8 | 62 | 18 | * | | |
| 58 | San Jose State University San Jose, CA | * | | | | | | B | 453 | 59.9 | 47 | 27 | * | | |
| 59 | The Art Institute of California-Argosy University Orange County Santa Ana, CA | * | | | | | | B | NR | 98.2 | 36 | 17 | | | * |
| 60 | The Art Institute of California-Argosy University Hollywood North Hollywood, CA | * | | | | | | | NR | 64.4 | 27 | 18 | | | * |

*Note*. Data for industrial design courses rankings from U.S sources as per Design Future Council (2009, 2013, 2014, 2016), Graphiq (2017), PayScale (2017), U.S. Bureau of Labor Statistics (2017b), U.S. Department of Labor (2017), and Europe as Q. S. Top Universities (2016, 2017).

***Table 4: 2017 U.S. industrial design courses and majors ranking (b)***

| | Name | SC | QS | QS Ranking | QS5 | DI D UG | DI D G | DI Q | SC R | Accept (%) | Grad (%) | S2T Ratio | Pub | Priv (NFP) | Priv (FP) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 61 | Pennsylvania College of Technology Williamsport, PA | * | | | | | | | NR | NR | 40 | 18 | * | | |
| 62 | Universidad Del Turabo Gurabo, PR | * | | | | | | | NR | 46.0 | 16 | 40 | | * | |
| 63 | Escuela de Artes Plasticas de Puerto Rico San Juan | * | | | | | | | NR | 92.7 | 27 | 13 | * | | |
| 64 | University of Wisconsin-Stout Menomonie, WI | * | | | | | | B | NR | 90.8 | 52 | 20 | * | | |
| 65 | Milwaukee Institute of Art & Design Milwaukee, WI | * | | | | | | B | NR | 59.1 | 55 | 10 | | * | |
| 66 | Walla Walla University College Place, WA | * | | | | | | | NR | 57.8 | 50 | 13 | | * | |
| 67 | The Art Institute of Seattle, WA | * | | | | | | B | NR | 51.3 | 30 | 19 | | | * |
| 68 | The University of the Arts Philadelphia, PA | * | | | | | | BM | NR | 69.6 | 57 | 8 | | * | |
| 69 | Philadelphia University Philadelphia, PA | * | | | | | | BM | NR | 63.9 | 61 | 13 | | * | |
| 70 | The Art Institute of Pittsburgh, PA | * | | | | | | | NR | 50.9 | 44 | 15 | | | * |
| 71 | The Art Institute of Philadelphia, PA | * | | | | | | | NR | 46.6 | 35 | 15 | | | * |
| 72 | The Art Institute of Portland, OR | * | | | | | | B | NR | 87.8 | 29 | 14 | | | * |
| 73 | Columbus College of Art and Design Columbus, OH | * | | | | | | B | NR | 88.6 | 55 | 12 | | * | |
| 74 | Cleveland Institute of Art Cleveland, OH | * | | | | | | B | NR | 67.0 | 60 | 9 | | * | |
| 75 | SUNY Buffalo State Buffalo, NY | * | | | | | | | NR | 61.6 | 48 | 16 | * | | |
| 76 | Pratt Institute-Main Brooklyn, NY | * | | 6 | | 5 | | BM | NR | 53.0 | 65 | 8 | | * | |
| 77 | The New School New York, NY | * | | 4 | | | | BM | NR | 65.9 | 65 | 10 | | * | |
| 78 | Fashion Institute of Technology New York, NY | * | | | | | | | NR | 44.3 | | 17 | | * | |
| 79 | Montclair State University Montclair, NJ | * | | | | | | BM | NR | 66.8 | 63 | 17 | * | | |
| 80 | Kean University Union, NJ | * | | | | | | B | NR | 70.4 | 50 | 17 | * | | |
| 81 | Lawrence Technological University Southfield, MI | * | | | | | | | NR | 57.4 | 52 | 11 | | * | |
| 82 | Ferris State University Big Rapids, MI | * | | | | | | | NR | 78.4 | 53 | 16 | * | | |
| 83 | College for Creative Studies Detroit, MI | * | | | | | | BM | NR | 45.6 | 57 | 9 | | * | |
| 84 | Wentworth Institute of Technology Boston, MA | * | | | | | | B | NR | 82.6 | 64 | 16 | | * | |
| 85 | Massachusetts College of Art and Design Boston, MA | * | | | | | | B | NR | 72.9 | 65 | 9 | * | | |
| 86 | University of Louisiana at Lafayette, LA | * | | | | | | B | NR | 55.8 | 44 | 23 | * | | |
| 87 | Columbia College-Chicago, IL | * | | | | | | B | NR | 88.5 | 41 | 13 | | * | |
| 88 | Savannah College of Art and Design Savannah, GA | * | | | | 5 | | BM | NR | 66.6 | 65 | 19 | | * | |
| 89 | The Art Institute of Fort Lauderdale Fort Lauderdale, FL | * | | | | | | B | NR | 52.1 | 39 | 20 | | | * |
| 90 | University of Bridgeport, CT | * | | | | | | B | NR | 60.7 | 32 | 17 | | * | |
| 91 | Metropolitan State University of Denver, CO | * | | | | | | B | NR | 65.1 | 25 | 19 | * | | |
| 92 | San Francisco State University San Francisco, CA | * | | | | | | BM | NR | 66.0 | 47 | 24 | * | | |
| 93 | Otis College of Art and Design Los Angeles, CA | * | | | | | | B | NR | 66.5 | 53 | 7 | | * | |
| 94 | California College of the Arts San Francisco, CA | * | | 28 | | | | BM | NR | 63.7 | 45 | 9 | | * | |
| 95 | Art Center College of Design Pasadena, CA | * | | 19 | | 3 | 1 | BM | NR | 80.9 | 70 | 9 | | * | |
| 96 | Academy of Art University San Francisco, CA | * | | | | | | BM | NR | NR | 32 | 16 | | | * |

| Nomenclature | | | | | | | |
|---|---|---|---|---|---|---|---|
| **DI:** | US Design Futures Council -Design Intelligence (DI): Deans Survey on Best Industrial Design Undergraduate Courses | | | | | | |
| **QS:** | UK Quacquarelli Symonds (QS) World University Ranking by subject from 76,798 academics opinions and scanned 28.5 million research papers | | | | | | |
| **QS5:** | QS 5 Stars: Maximum ranking in Research, Teaching, Internationalization, Specialist Criteria, Employment, Facilities, Innovation, Inclusiveness | | | | | | |
| **SC:** | StartClass RankSmart is based on academic excellence, admissions selectivity, career readiness, financial affordability, and expert opinion (US News, Forbes, and more) | | | | | | |
| **DI UG:** | Deans Survey Undergraduates | **DI G:** | Deans Survey for Graduates | **DI Q:** | Qualification Granted | | |
| **SCR:** | StartClass Ranking | **Accept:** | Acceptance Rate | **Grad:** | Graduation Rate | | |
| **S2T:** | Student to Teacher Ratio | **Pub:** | Public | **Priv:** Private | **NFP:** | Non-for Profit | **FP:** For Profit |
| **B:** | Bachelor | **M:** | Masters (including Postgrad) | **NR:** | Not Rated | | |

At last count, 2,925 industrial designers were mainly concentrated in New South Wales (990, 33.8%) and Victoria (1,223, 41.8%). 362 registered companies (12 more after a decade) employed 1,725 designers (10 average per firm). Major markets were packaging (32%), commercial infrastructure (21%), home goods (19%) and consumer goods (16%). However, the two main employment sectors, manufacturing (49%), and professional, scientific and technical services (32.8%), have trended down for 30 years. National manufacturing's GDP plummeted by 2013 (6.8%). A further drop is expected following the 2017 car industry shut down (5%) which has impacted mainly Victoria (200, 15%). High-tech exports (2.3%) are not filling the void as several companies have left the country.

Other fields of employment, like retail (8%) and construction (3%), do not show significant change (Andersen, Ashton, & Colley, 2015; Australian Bureau of Statistics, 2013, 2017; Cahill, 2010; Creative Industries Innovation Centre, 2015; Cully, 2016; Dixon, 2013; Dos Santos Duisenberg, 2010; Labour Market Information Portal, 2017; Roberston, 2013a, 2013b; G. Roos, 2012; Wright, Davis, & Bucolo, 2013). Academically, 29 universities and technical and further education institutions (TAFE) deliver design content. Universities offered 14 Bachelors, 5 Masters, 6 PhD courses specifically. One university's course made the top 25, and five universities had the 50 best Bachelors in world rankings. Graduations are unregulated and increasing over a shrinking market demand, despite statistical estimates of 2% per year growth and forecasts of 800 more new jobs by 2020 (Australian Bureau of Statistics, 2013). Industry and academic experts who were interviewed during the project recommended redefinition, since education did not clearly teach new competencies to compete internationally. Accordingly, several courses have changed to names such as 'product innovation' and 'integrated product design' (BachelorsPortal, 2017; HotCourses, 2017a, 2017b, 2017c, 2017d; Q. S. Top Universities, 2016; StudyPortals, 2017; University of South Australia, 2017).

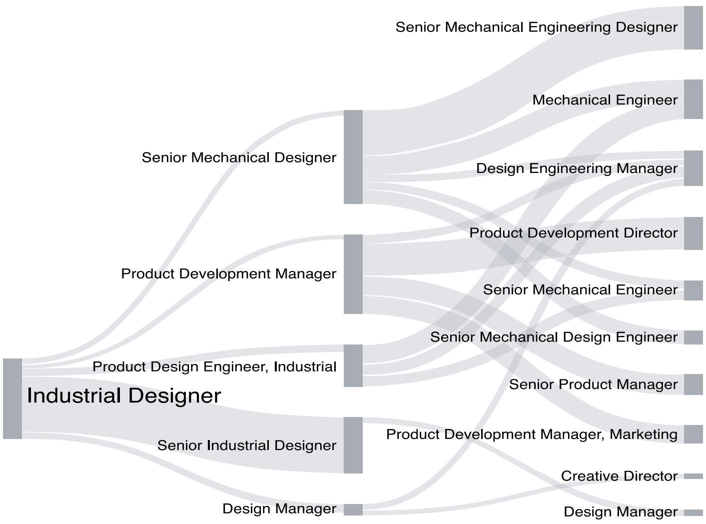



***Figure 8: U.S. traditional pathways for industrial designers. Reprinted from PayScale, 2017, Industrial Designer Salary, by PayScale Human Capital, retrieved from https://www.payscale.com/research/US/Job=Industrial_Designer/Salary, Copyright © 2018 PayScale, Inc.***

## Digitalisation Benchmark

Curriculum development also needs to deal with disruptive technologies, such as ICT. Design education should be well suited for digitalisation since its participants are thought of as innovators. However, the education business in general has proven slow to adapt to digitalisation. Often top-down management buys quickly into these types of infrastructure investment, while academics in *abandoned, soft* and *hard-centre* learning models may be reluctant to change. Inertia against technology adoption follows a model that has seen higher education rarely disturbed by innovation for 100 years. Still, the impending change follows a known pattern. Expertise does not necessarily lose to better replacement, but cheaper and simpler know-how that later improves and displaces the incumbent (Christensen & Eyring, 2011). Meanwhile, students are generally thought as digital natives who are comfortable with change. Yet, international research demonstrates higher digital use does not necessarily equate to innovative learning (Carneiro, 2011).

Using the U.S as a benchmark, university-wide multi-year studies such as Chen, Seilhamer, Bennett, and Bauer (2015) revealed students' mobile technologies in education generally turn into greater social networking, music, social media, navigation, entertainment, photography and games, for above-learning use (Figure 9). Similar in Australia, our university supported digitalisation of learning and mobile technologies. It is worth mentioning a 2012-2015 iPad project for all first-year students that has now converted to a BYOD (acronym for Bring Your Own Device) initiative (Kirkpatrick, 2017; Russell, 2014; Russell & Jing, 2013). By 2017, students had greatly shifted to mobile and online use alongside up-surging devices like iPads (Figure 10). The data did not specify learning quality though, while registering hit rate for access to apps and information. Still, it is indicative that social networking, teacher vodcasting and web sharing increased. Otherwise, digital tools use that lean towards active learning and communication, such as lecturer-student emails exchange, making web pages, blogs, virtual worlds and sims, stayed the same or diminished (Figure 11).

Research is gradually uncovering shortcomings of a global rave for digitalisation in favour of massification of learning and economies of scale. Older generations do not adopt and use new technology at the rate expected, while younger generations, Millennials and Generation Z (GenZ), communicate with mobile consumer-like tools but find difficulties working at higher-level thinking. Digitalisation is changing their capacity to think, read, store, recall and convert information into knowledge (Allen, 2015). Bettinger and Loeb (2017) discovered many students fare worse through online learning than traditional classes, since they cannot follow process, take action or elaborate deep meaningful reasoning (Carr, 2011). Microsoft measured increasing media consumption, digital lifestyles and multi-screening decreases users' ability to focus, learn and filter distractions by an average of 8 seconds (Gausby, 2015). Deloitte Touche Tohmatsu (2017) also found cultural gaps among digital natives. Millennials said GenZ are less prepared (e.g. experience, patience, maturity, integrity) and need to be humble, willing to learn and work hard.

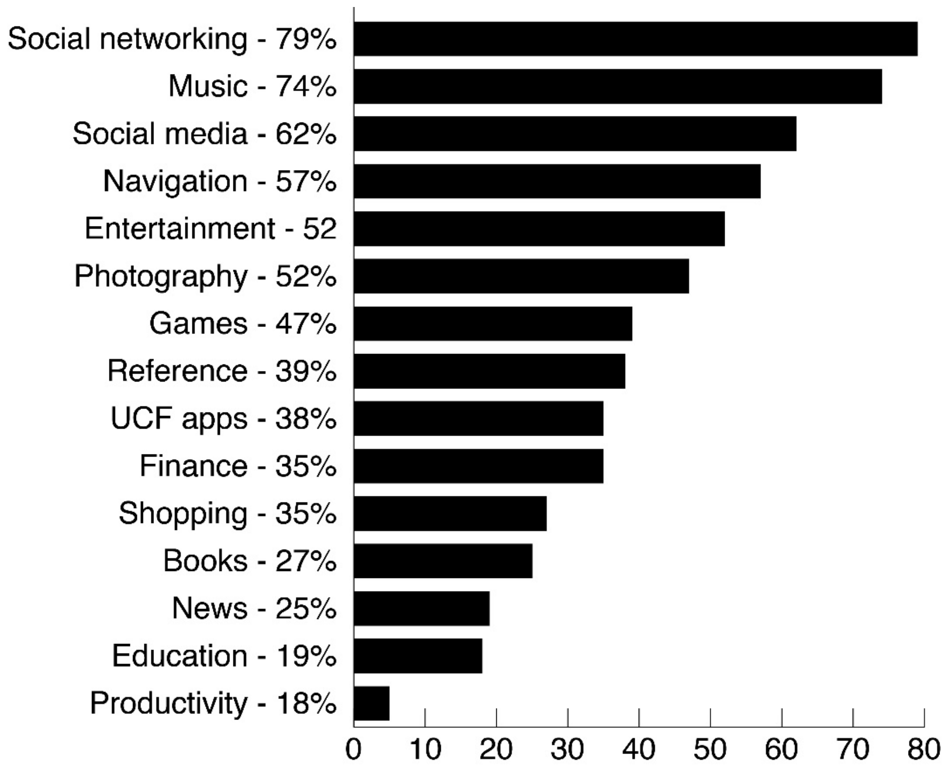



***Figure 9: 2012-2014 University of Central Florida most popular personal app use per category (N=1,181). Reprinted from Chen, Baiyun, Seilhamer, Ryan, Bennett, Luke, & Bauer, Sue. (2015), Students' Mobile Learning Practices in Higher Education: A Multi-Year Study. Educause Review, 7.***

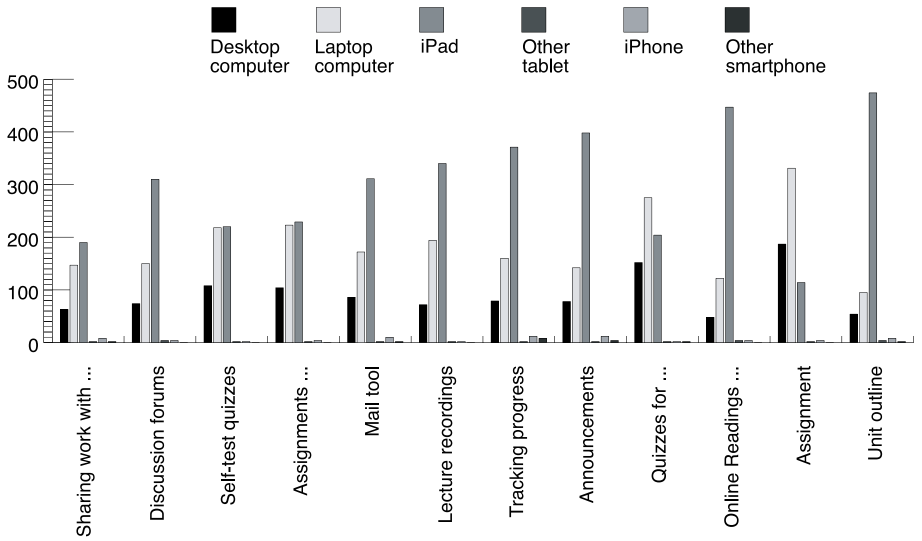



***Figure 10: Students shift to mobile devices Reprinted from Kirkpatrick, Denise. (2017), Learning and Teaching: Digital Strategies and Enabled Environments, Keynote presented at the University of Canterbury's Teaching Week Christchurch, New Zealand.***

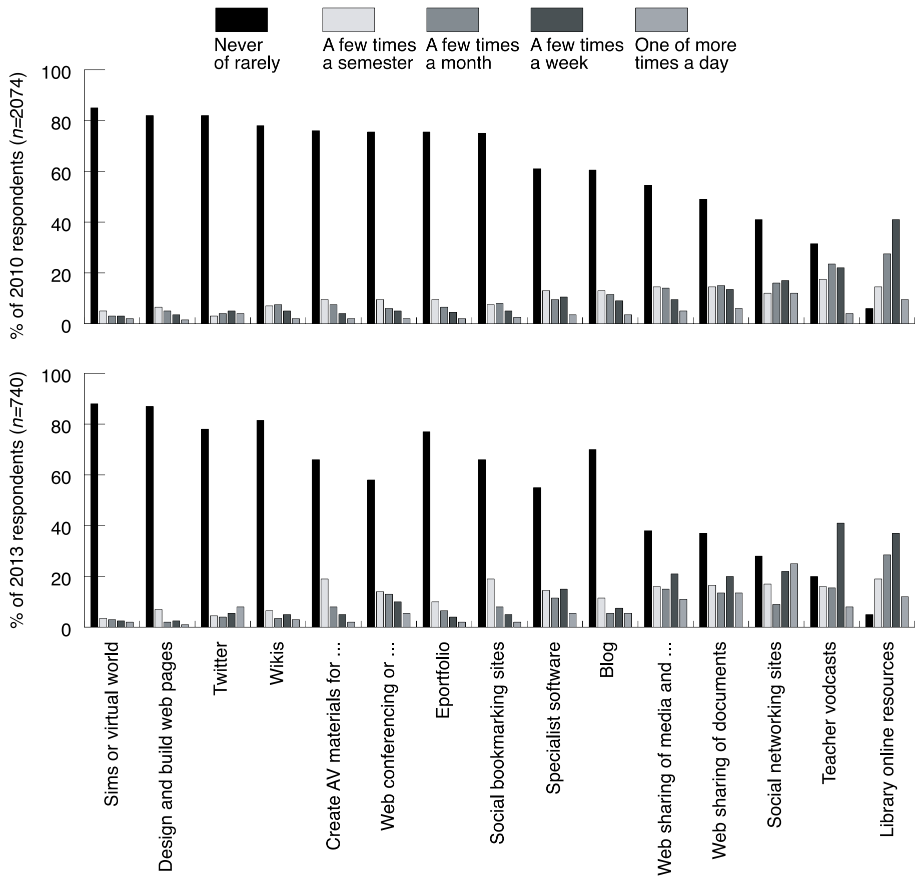



***Figure 11: 2010-2013 Frequency of online study activities Retrieved from Russell, Carol. (2014), Herding Cats And Measuring Elephants: Implementing And Evaluating An Institutional Blended And Mobile Learning Strategy. Rhetoric and Reality: Critical perspectives on educational technology, 211-221, Copyright © 2013 Christopher Allan, Mark Symes, and Jill Downing***

## New Curriculum

The Australian circumstances of the course redesign were unique. A new curriculum needed to address the industrialisation and declining of education standards, digitalisation and globalisation while capitalising on academics' traditional skills, students' cultural-historical background, and design capacity to trigger social construction of knowledge by promoting participants' adaptable elastic mind and imagination (Antonelli, 2008). Assessing students' skills and incumbent teaching models were critical to comprehending the potential and obstacles that might influence design intervention and adoption of a new curriculum.

Analysis of students interviews and outcomes from first year onwards revealed that their array of skills and retention rate (close to 50% rate) echoed those of larger national and international assessments. The OECD Program for International Student Assessment (PISA) and Australian National Assessment Program - Literacy and Numeracy (NAPLAN) data revealed a decrease of STEM skills coming from high-school regardless of high or low performers. This is at a time when 75% of the fastest growing occupations require STEM skills (Ainley & Gebhardt, 2013; Australian Industry Group, 2015). Higher education was rigid because slight customisation meant high bureaucratic cost (Corneli & Danoff, 2011). The Australian uncapping of supply of Commonwealth-supported places (CSPs) in universities made it difficult to keep cohort equity because there was no longer a minimum skill set on the low performers' side (Harvey, 2016). The cohort was characterised by more than 100 ethnicities, with 62% being first in a family at university, 39% speaking a different language at home, and 27.9% being from low socio-economic status (Centre for Western Sydney, 2017).

The industrial design curriculum was also a mix of teaching models. The program had strong institutional *universal* preconditioning based on Bloom's taxonomy (*hard-centre)*, whilst academics handcrafted teaching based on technical skill transmission (*abandoned-centre)* that replicated traditional disciplines. All students' needs, interests and abilities were treated the same (Twigg, 2003) in a manner of social reproduction that maintained pervasive inequalities. The lecturer-to-student ratio was 1:25 officially. However, classes were often run with 1:30 or more. Instruction was greatly based on general knowledge (e.g. materials sciences, ergonomics, 3D CAD drafting) and assumptions on design's final users and market. The course only ventured into initial design inquiry and practice-based research in the final semester of the course.

A behavioural, cultural and epistemological break was needed to enable a curriculum change based on practice and object-oriented social construction of knowledge. Bourdieu helped in contextualising design education as practical logic that allows habitus to escape from a subject-object dichotomy through free choice (agency). Habitus means the internalised social system of being, seeing, acting and thinking since young age. A plurality of views was key to learning how to deal with the uncertainty of power play and social position within the design program (Bourdieu, 1984, 1990; Bourdieu & Biggart, 2002; Bourdieu & Passeron, 1990). Design agency needed to avoid intellectual bias that objectifies participants and requires undisputed acceptance of traditional good design and aesthetics definitions (taste). This was no easy task as incumbent mechanisms tried to keep status quo. Nonconforming individuals risked alienation. Consequently, academic reproduction risked failing the design imperative of leading by innovation. Participants deserved to reprise design learning and innovation as three types of capital: academic capital as a new discourse based on continuity among practice and theory; cultural capital to embody social and symbolic assets (e.g. authority, education, goals, qualifications, taste); and design capital by *redesigning* curriculum through

1. Renovating attitudes, behaviour and skill,
2. Allowing predisposed influences into the learning experience (e.g. outside experiences, family, relations),
3. Avoiding inequalities and academic divisions (e.g. lecturer, student), and
4. Promoting a new culture of learning.

Socio-cultural benefits would come from a collaborative community that raised the bar from skills to competencies (know-how collections) and convert all participants into engaged practitioners in joint enterprises, shared repertoires and transdisciplinary integration. Learning by tinkering was to help develop a new learning environment based on playing with artefacts and data to find new information, building knowledge, fostering imagination, creativity, peer-to-peer (P2P) sharing, and open networking (Engeström, 2013; Thomas & Brown, 2011).

ASA clarified social construction of knowledge complexity when placing participants (academics, institution, students), internal and external scenarios in the same space-time paradigm. Rules, outcomes, objects and divisions of labour depended on social positions. The institution applied infrastructure and management measures aiming to precondition competitiveness, excellence and profit. Academics focused on keeping graduation numbers up to protect their course survival and saw top-down administration and application of technology as interference (e.g. campus relocations, ICT). Students had limited understanding of benchmarks on design, education, and industry excellence. Therefore, they normally fitted to status quo, believing that was the best way to obtain good qualifications and future employment. As per Engeström (2008), these were opposed, rather than shared views, that unleashed *runaway objects* that either hindered participants' outcomes if interference was dictated and unexplained, or encouraged them into meaningful learning if they were able to contextualise and participate in that disruption (Figure 12). Therefore, the ASA analysis revealed that a foundational base was needed, for:

1. Continuous leadership to shift from old to up-to-date design education;
2. Periodic ASA snapshots on process (semester and year to year diagnosis), based on specific space (the interval between artefacts) and time (the interval between events);
3. Building common ground for collaborative activity among participants (academics, institution, students) to facilitate radical emancipatory possibilities for design education.

Hence, small exemplars with participants were developed (e.g. assessments, units) to later apply to larger curriculum change. Students and academics forums were held over three years. Participants built capacity from insight, imagination and foresight. Eight curriculum advisors, industry experts and an external advisory committee contributed. Students were open to curriculum reformulation. They noticed differences between the old course and their everyday experiences. Interestingly, two thirds of academics saw no need for change. Then, one third proposed changing back to artistic illustration. Another wanted more 3D CAD drafting. Both views echoed national shortcomings, regarding translation of education investment to innovation, that believe teaching is about transmitting operational skills instead of building new knowledge (Innovation and Science Australia, 2017). A last group believed the course missed the increasing convergence between design and algorithms, bioengineering, cybernetic intelligence, computer sciences, cultural studies, HCI, ICT, user experience (UX), and HCD since 1960s electronic age (Brand & Rocchi, 2011; Cross, 1993; Overbeeke & Hummels, 2014).

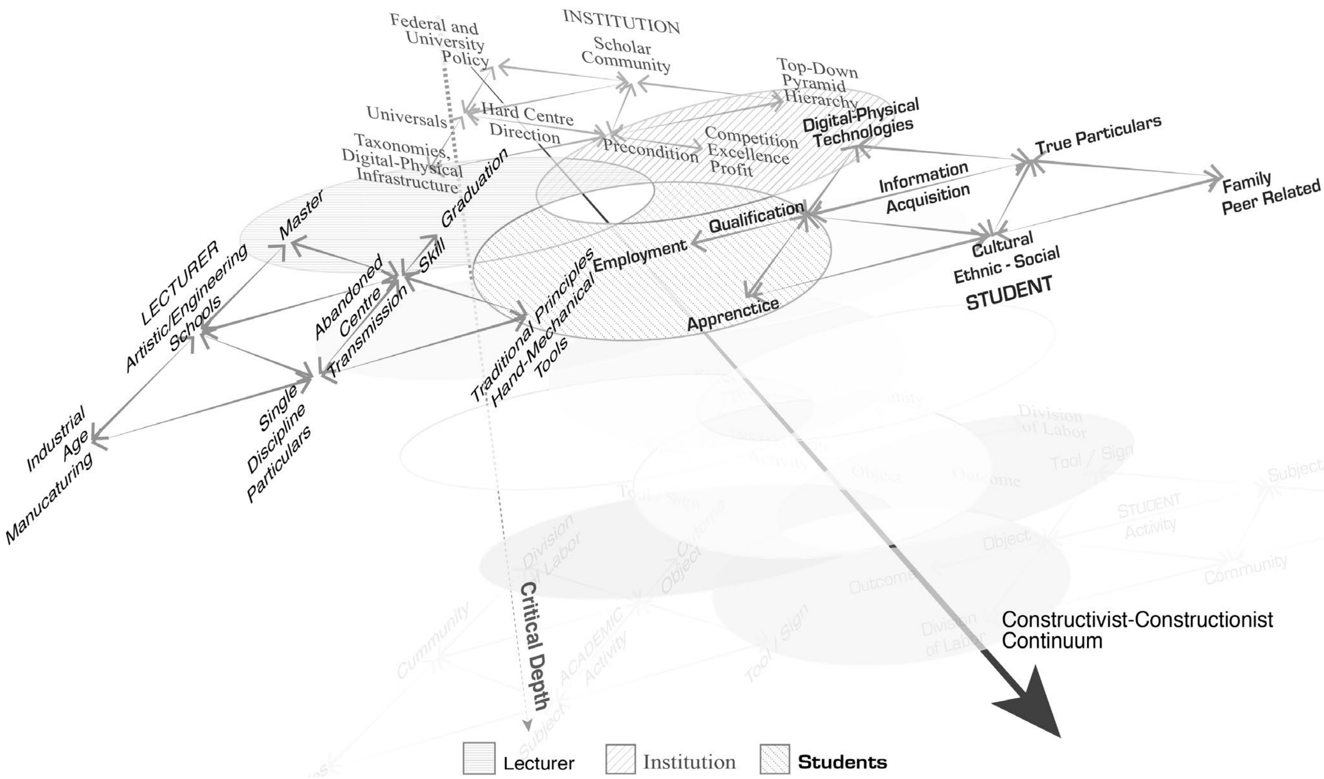



**Figure 12: Participants' ASA evaluation within space-time paradigm. Reprinted from Author, 27 October 2014, Industrial Design Curriculum 2016: New Vision and Imperative, Unpublished internal document.**

A vision and mission were written for the first time for the course to assist participants to *collaboratively bring up creativity, innovation and entrepreneurship* into our School of Computing, Engineering and Mathematics which has 22 undergraduate and 18 graduate courses. Participants had to become *independent all-rounders working responsibly, sustainably and transdisciplinary to add value to users, society and industry in today's creative economy*. Curriculum renewal followed Bauhaus, HfG Ulm, Malmö, and recent manifestations of open school movement. It took Dewey's learning-by-doing further to Papert's constructionism (situated project-based learning building and internalising new knowledge) and Brown's entrepreneurial learner who knows by finding and evaluating (*homo sapiens*), learns by building content and context hands-on (*homo faber*) and creates new culture by playing and experimenting (*homo ludens*) with lateral thinking and feeling, not just logical calculus (Brown, 2013; Harel & Papert, 1991; Papert, 1986).

The new curriculum aligned with critical pedagogy through *critical design and making* as *material speculations* that reconnect conceptual, linguistic, physical and digital acts of knowing, discussing and thinking with artefacts (Freire, 1970; Wakkary, Odom, Hauser, Hertz, & Lin, 2015). *Critical design* prototyped artefacts that challenged everyday reinforcing of status quo (*affirmative design*) to query product optimisation and social norm (Dunne, 1999; Dunne & Raby, 2001). *Critical making* by iterative prototyping witnessed a constructionist process reconnecting critical thinking (abstract, explicit, cognitive, linguistic) with material, tacit, embodied, external and community-oriented making (Ratto et al., 2011; Ratto & Hockema, 2009). Computers were intervened with coding and physical intervention more than just using them as consumer-like tools (e.g. MS Word, Photoshop, SolidWorks). STEAM supported CDIO (conceiving, designing, implementing, operating) framework that validated design by proving it works practically (use, adoption). Instead of accepting design as completed and successful at concept proposal stage (conceiving), as had been done previously.

Transition into the new program was staged progressively and the curriculum was inverted. As an example, a new unit called *Contextual Inquiry* replaced and moved the only third year design research unit in the old course to first year and semester with the name *Introduction to Industrial Design Methods*. Likewise, the course's Design Studio stream increased from 4 to 6 units that now started in the first year and semester instead of the second year. Students had to build a fresh discourse that helped in working out their predisposed influences through applied research and tinkering from first day in the course. Design value relied on openly identified, discussed and accepted knowledge that has specific history, culture, people status and available technology. Lecturers and students started with what they knew, to later dive deeper and solve social and technology relations. Then, they enabled users and themselves to mix and create new experiences and projects through bottom-up maker, hacker culture, and networked platforms independent from traditional experts (Lessig, 2008). The new course contained a curriculum structure three-dimensionally wrapped around a digital spine called Lab Space (Figure 13, Table 6), that connected all levels of critical depth represented horizontally (technical skill), vertically (length of schooling), diagonally (social construction of a continuum of constructionist-constructivist learning). It also capitalised on digitalisation and P2P through:

- Maker Hub (Makerspace, Hackerspace, FabLab, TechShop)
- Individual ePortfolios as open reference on progress from first-year
- Industry projects increasing in complexity from first year
- Design Factory model-like in senior years intending to bring together researchers, students, industry partners and entrepreneurs in working integrated learning approach to solve complex challenges (Aalto University, 2008).

Specifically, ePortfolio was chosen as a constructionist digital instrument to assist changing students' habitus. They would use it as a learning space to gather and share information, recall memory, ideate, research, and develop new design narratives through heuristic prototyping and experimentation. This researcher sought university funds for this as a project; it grew to supporting a three schools pilot from 2012 to 2014 (Table 7). The University chose Pebble+ platform since it worked as Blackboard add-on. Pebble+ allowed scaffold learning as active reflection and presentation, private and networked sharing, discussion and feedback. Pilot Schools had different views about ePortfolios. Subsequently, two of the Schools dropped out. They treated ePortfolios either as basic Dropbox file repositories or as online MS Word processing (e.g. essays, CV file attachments). Students found ePortfolios unintuitive, confusing and unfriendly since templates, rubrics and text formatting were difficult, and became reluctant to use them. They frequently lost their unsaved essays while trying to format work live without saving (Blom, Rowley, Bennett, Hitchcock, & Dunbar-Hall, 2013; Mason, Langendyk, & Wang, 2013; Rowley, Bennett, & Blom, 2014).

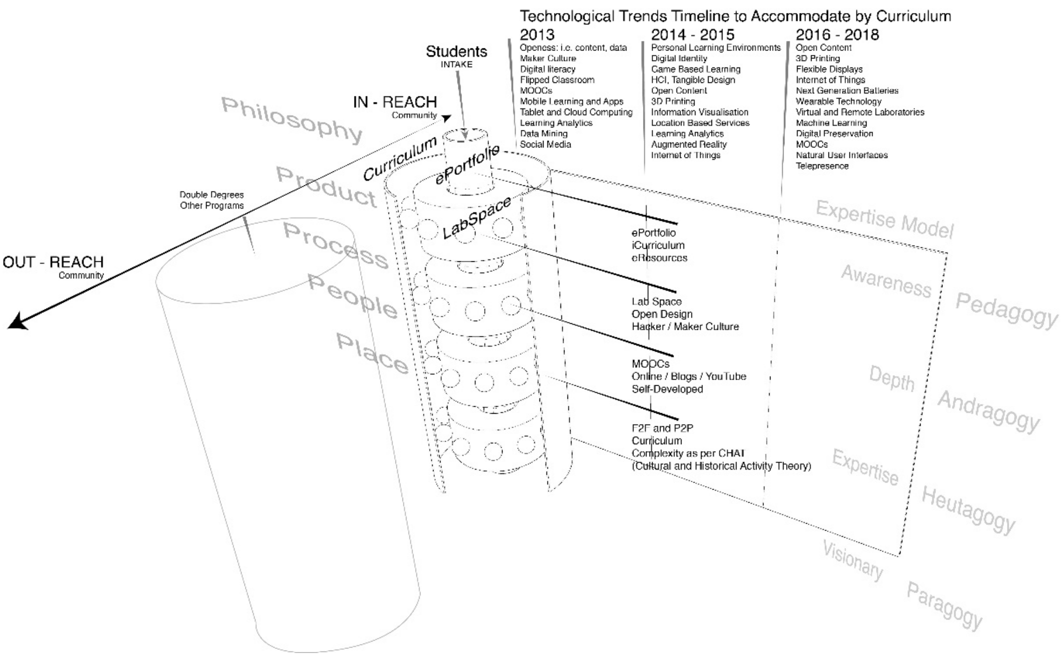



***Figure 13: New design curriculum within space-time paradigm. Reprinted from Author, 27 October 2014, Industrial Design Curriculum 2016: New Vision and Imperative, Unpublished document.***

By contrast, industrial design students' work was called sophisticated and is still in use (Figure 14). As per Black and Rankine (2013), weekly ePortfolio work was intended to "reinforce the different aspects of design process, emphasising the importance of visual and structural planning alongside textual descriptions". They collaborated on a range of design projects to "demonstrate their research and development process through submission of rich media evidence such as diagrams and videos as well as discussion and reflection". These students had higher demand use than other participants because of the need for designer and user control typical to this creative field. Admittedly, they initially had mixed responses to regular feedback on design process. Characteristically, students needed to modify any habits to work weekly with frequent constructive critique, design heuristics and some constraints due to ePortfolio software development (e.g. video format). Interestingly, several managed to personalise their ePortfolios by hacking the system (HTML5) before and after making them public to the internet. Participants who used ePortfolio the most were also those who performed best overall.

The four-year curriculum progressed alongside an evolution timeline, from *pedagogy* to *paragogy*, where a collaborative community reached inwards to the discipline and outwards to other degrees and industry. The first year focused on product making, introduction to design research, learning by playing, experimenting, tinkering, and general knowledge. The second year added process and methodology. The third year concentrated on people and behaviour, and the fourth year enveloped all and contextualised complexity as per place and time. Course attention expanded from assembly and manufacturing to HCD, design research and intermediation of human experience, new sociotechnical parameters as preeminent model of modern organisation, new maker culture, industry 4.0

and open design (e.g. physical-digital artefacts, machines and systems built on shared information, free open-source software, hardware). As per several authors, including Gibson (2014); Maier and Fadel (2001); (2009); Norman (1999); (2013), this development catered for artefacts and systems potential actions to construct knowledge (*affordances)* beyond industrial age parameters. Also, action possibilities, which are normally latent in the environment until perceived by humans and animals, had by now evolved onto artefact to artefact *affordances* that sense each other and act without human intervention (e.g. algorithms, Google bots, Internet of Things).

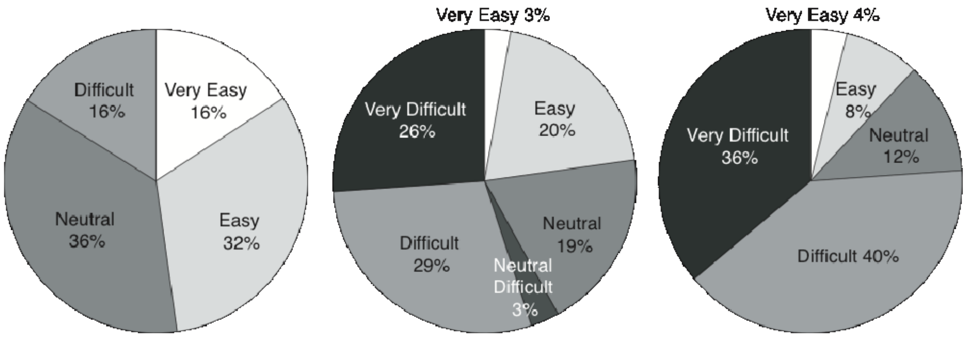
***Table 6: Course including ASA diagnosis, Lab Space, International Design Studio, Design Factory***

| | Industrial Design Curriculum | | | | | | | LabSpace | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | P2P & MakerHub | ePortfolio & Connected |
| (x) Unit Level | | Core | Alternate | | | | | Industry projects convert to unit credit or industrial Experience requirement | |
| | | | | | | | Diagnosis | | |
| | | | Major 1 | SubMajor 1 | Major 2 | SubMajor 2 | | | |
| | Design Research Methods | Design Studio Stream | Graphics & Visualization | Human Interaction | Des. Management & Entrepre-neurship | Responsible Design & Sustaina-bility | STEM foundation | | |
| 1 A | Intro to ID Methods (1) | DS1: Patterns & Products (1) | G1: 2D/3D ID Communi-cation (1) | | | | Design Science (1) | P2P Math and literacy (e.g. PASS, MESH) | YouTube, MOOCs and other digital tools for self-learning drawing, drafting, materials, technology, etc. |
| 1 S | | DS2: Form & Production (2) | G2: 3D Engineering Specs & Vis (2) | Program-ming Fun-damentals (1) | | Sustainable Design: Materials & Technology (1) | Math for ID (1) | Events and Competition (int-extern), Low-level MakerHub projects | Managing material information and tools: Granta Connexions |
| | | | | | | | Diagnosis | | Diagnosis |
| 2 A | | DS3: Design Process & Function (3) | G3: Visual Simulation (2) | HCI (3) | DM1: Product Process (2) | | | Mid-level MakerHub projects: Social Impact. Industry competition | MOOCs: - Urich - Norman - Etc. |
| | One Major / Sub-Major Alternate or Elective | | | | | | | | Diagnosis |
| 2 S | | DS4: Innovation through CDIO (3) | G4: Kinetic Narratives (3) | Tangible Interaction Design (3) | DM2: Manufacturing & Supply Chain (2) | Sustainable Design: Product, System, Services (2) | | High level MakerHub Project: Social impact, TID, HCI, machine learning, robots, etc. Industry and Design competition | CDIO. Gaming and experience. Service and system design |
| | Two Major / Sub-Major Alternate or Elective / Industrial Experience | | | | | | | | Diagnosis |
| 3 A | | DS5: Symbol & Meaning Making (4) | G5(4): Creative Computing | 300976(2) Tech for Mob Apps | DM3(3): Org Skills for Designers | | | | Critical making. Collective Networked thinking |
| | Two Major / Sub-Major Alternate or Elective / Industrial Experience | | | | | | | | Diagnosis |
| 3 S | Contextual Inquiry (4) | DS6: Ambient, Place & Behavior (4) | | | DM4: Strategy, Lean Startup & Entrepre-neurship (4) | | | Design Factory: Design and industry research and innovation teamwork for social impact and new knowledge | Critical research and design. International Design Studio |
| | Two Major / Sub-Major Alternate or Elective / Industrial Experience | | | | | | | | Diagnosis |
| 4 A 4 S | Honours | | | Coursework | | | | | |
| | | | | | | | Diagnosis | | Diagnosis |

*Note*. Reprinted from Author, 27 October 2014, *Industrial Design Curriculum 2016: New Vision and Imperative*, Unpublished internal document.

***Table 7: Pebble+ ePortfolio project Likert scale for three schools as per Black and Rankine (2013)***

| **Industrial Design at School of Computing, Engineering and Maths** 50 students Design Studio 4 | **Music at School of Humanities and Communication Arts** 80 students Music Project | **Medicine and Surgery Year 1 and 2 at School of Medicine** 200 students Personal and Professional Development |
|---|---|---|
| Likert Scale Results<br>Question: **How easy did you find using Pebble+?**<br>Measured from 1 Very Easy to 5 Very Difficult | | |
| Easy – Very Easy: **48%**<br>Difficult – Very Difficult: **16%** | Easy – Very Easy: **26%**<br>Difficult – Very Difficult: **55%** | Easy – Very Easy: **16%**<br>Difficult – Very Difficult: **76%** |




*Note*. Reprinted from Black, Elizabeth, & Rankine, Leanne. (2013). *Pilot Evaluation Report - PebblePad, Part 1*. Retrieved from Internal document (previously available in university website)

***Figure 14: Constructivist and constructionist industrial design ePortfolio use. Reprinted from Author, 27 October 2014, Industrial Design Curriculum 2016: New Vision and Imperative, Unpublished internal document.***

Bloom's Taxonomy was a bridge among disciplines (Anderson et al., 2001) but offered limited freedom to redefine design education. So, 12 unique course learning outcomes (CLOs) were developed afresh for the program. These shifted from the *hard-centre* and *abandoned-centre* models to a *liquid-centre* model, focused on both, empowering participants as agents of change and innovation based on creative intelligence parameters. CLOs started with *Exploring* and *Discovering* via research and knowledge mining before Bloom's stage of *Remember*. Design does not start with remembering, but inquiring what problem to disentangle. *Framing, Evaluating, Applying* and *Working* promoted framing and solving new knowledge landscapes through serious play (e.g. metaphor, 3D probing, scenario building), game theory (e.g. strategic decision-making), critical design and making (J. Roos & Victor, 1998, 1999; 2004). These activities connected the physical-digital gap with associative exploration pivoting between relations, concepts, prototyping, testing and scaling solutions to final artefact or service. Bloom's stage *Create* was diversified into 6 as *Producing, Delivering* and *Envisioning* artefacts that mark future trends, *Innovating* behaviours, products and services, *Creating* meaningful and effective sustainable solutions, and *Leading* by transcending affirmative design and social reproduction (Table 8).

Skills were grouped into competency envelopes. Per benchmarks (e.g. d.School, RISD, TU Eindhoven), they assisted in constructing design intelligence spaces that transcended disciplinary boundaries. *Being in space* completed the last century's definition of *being in time* for artefacts, disciplines and users. It acknowledged that thinking, doing and making happen in networked and hybrid human *spaces of coexistence*. This is the common ground among *runaway objects* that *instantiate* successful design and learning through interaction (Heidegger, 1962; Latour, 2009; Sloterdijk, 2011). Four envelopes containing skills for Making, Interaction, Visualisation, Strategy and Decision Making (Figure 15) fitted the new curriculum through user experience and new forms of manufacturing as knowledge-based innovation (biological, electrical, interactive, mechanical) amid users, users and artefacts, and between artefacts.

Starting with Dreyfus' cognitive acquisition model (Dreyfus & Dreyfus, 1980), the new course units built students' initial aptitudes up to ability dealing with novel design learning narratives (Product-Production, Process-Method, People-Participation, Place-Time-Practice). Students started as *Naïve* participants in first year. They became aware and empowered learners who increased their ability (e.g. gained depth, competency and proficiency) from *Novice* to *Advanced Beginners*. Several trials indicated they did learn by self-diagnosis (e.g. ePortfolio). *Expertise, Mastery* and *Visionary* stages were the result of transformative learning and ownership (e.g. practical wisdom, designing, making) capable of generating new knowledge, artefacts, experiences, and ecosystems (Table 9). Four new specialisation tracks were proposed for fourth year Honours program in the course. These dealt with industrial design's physical-digital challenges set as pathways for new mindset, theories and ways of designing that help transitioning into new ecosystems, lifestyles and society infrastructures: Human Environments, Responsible Design, Human-Centred Design, and Technology Development. Based on these same four design research concentrations, these pathways were discussed for further double degrees and postgraduate courses (Masters, PhD) to be considered in a next curriculum development.

***Table 8: Industrial design course learning outcomes aligning with Creative Intelligence.***

| Bloom Anderson, Krathwohl 2001 | ID Course Learning Outcomes Novoa 2011 - 2013 | Descriptor | Creative Intelligences Nussbaum 2011 |
|---|---|---|---|
| | **1. Explore** and discover market and user demands through design based research and contextual inquiry | Design based research | 1. Knowledge Mining |
| Remember | | | |
| | **2. Frame** novel problems defined by environment, people and systems | Framing and defining problems | 2. Framing |
| Understand | | | |
| | **3. Evaluate** complexity through interaction between products, processes, people and places | Evaluating complexity | 3. Playing |
| Apply | | | 4. Making |
| | **4. Apply** knowledge and skills to problem solving in a variety of fields deriving from traditional industrial design literacy to modern circumstances of human behavior, experience and interaction | Problem solving | |
| Analyze | | | 5. Pivoting / Scaling |
| | **5. Work** responsibly and collaboratively according to values and principles dictated by professional code, culture and society | Teamwork and values | |
| Evaluate | | | |
| | **6. Contribute** to the community and business by demonstrating management and entrepreneurial qualities | Entrepreneurship and management | |
| Create | | | |
| | **7. Produce** functional and efficient market ready products using tangible and intangible materials according to needs and manufacturing constraints | Producing products | |
| | **8. Deliver** systemic solutions to produce designs that fit, adapt and improve human condition and sustainability | Systemic process | |
| | **9. Envision** future trends by managing ambiguity through critical thinking, logic, scientific reasoning and foresight. | Scientific thinking and foresight | |
| | **10. Innovate** on behaviors and products from basic research to well defined incremental, breakthrough and disruptive transformation | Transformation | |
| | **11. Create** new meaningful and sustainable ideas, structures and systems transcending typical innovation | Creativity and invention | |
| | **12. Lead** by example as agents of change to benefit environment, people and systems in our technology driven society. | Lead change | |

*Note*. Data for CLOs from (Author, 2011 – 2013), for *Bloom Taxonomy* from Anderson et al. (2001) and for *Creative Intelligence* by Nussbaum (2013).

Contrary to earlier academics' fears, the new curriculum also attracted support and endorsement from school, university and outside community (academic, industry). Positive results showed along exemplar trials and when larger curriculum change occurred. This was a University-funded course change (over AUD 1.5 million) that evidenced prompt positive outcomes. It is worth noting that the industrial design ePortfolio project led to it being categorised as university exemplar in the area. Additionally, student retention improved, together with Student Feedback on Units (above school and university means for trial units), alongside the implementation of a collaborative and computing learning lab, design workshop, 3D printing lab (24 prototype machines from low to high fidelity and materials), MakerSpace and initial TechShop, software licenses that facilitated informed knowledge (e.g. material intelligence Granta CES Edupack), HCI and UX implementation with open source software support (e.g. Arduino, C++, Processing, Unity), and traditional tools and machinery. Renewed students' self-esteem was evidenced with participation in national competitions. First, second and commendation awards had no course precedent in events conventionally dominated by other universities (Cormack, 2013 - 2015). The

MakerHub concept benefited *work-integrated learning* that included Aalto Design Factory model-like projects.

Industry partners wanting to transform from traditional manufacturing to knowledge-based and design-driven innovation were attracted by this culture change towards the creative industries. Public acknowledgements were encouraging. As with a citation by The Creative Industries Innovation Centre, UTS Innovation and Creative Intelligence (Andersen et al., 2015) in relation to assisting Infasecure, a leading company in child safety and car restraint devices, to strategise design-driven innovation. An academics and students team led by Professor Mark Armstrong (Monash University) and this author assisted the company to deliver business growth, their first R&D industrial design department, and full employment for the participating students. Students' projects specifically aimed to improve children car safety and diminish driver distraction by introducing physical-digital industrial and HCI design intelligence. Sensors in seats and buckles detected child behaviour and symptoms to communicate with parents through colour, sound and wireless communication (Figure 16).

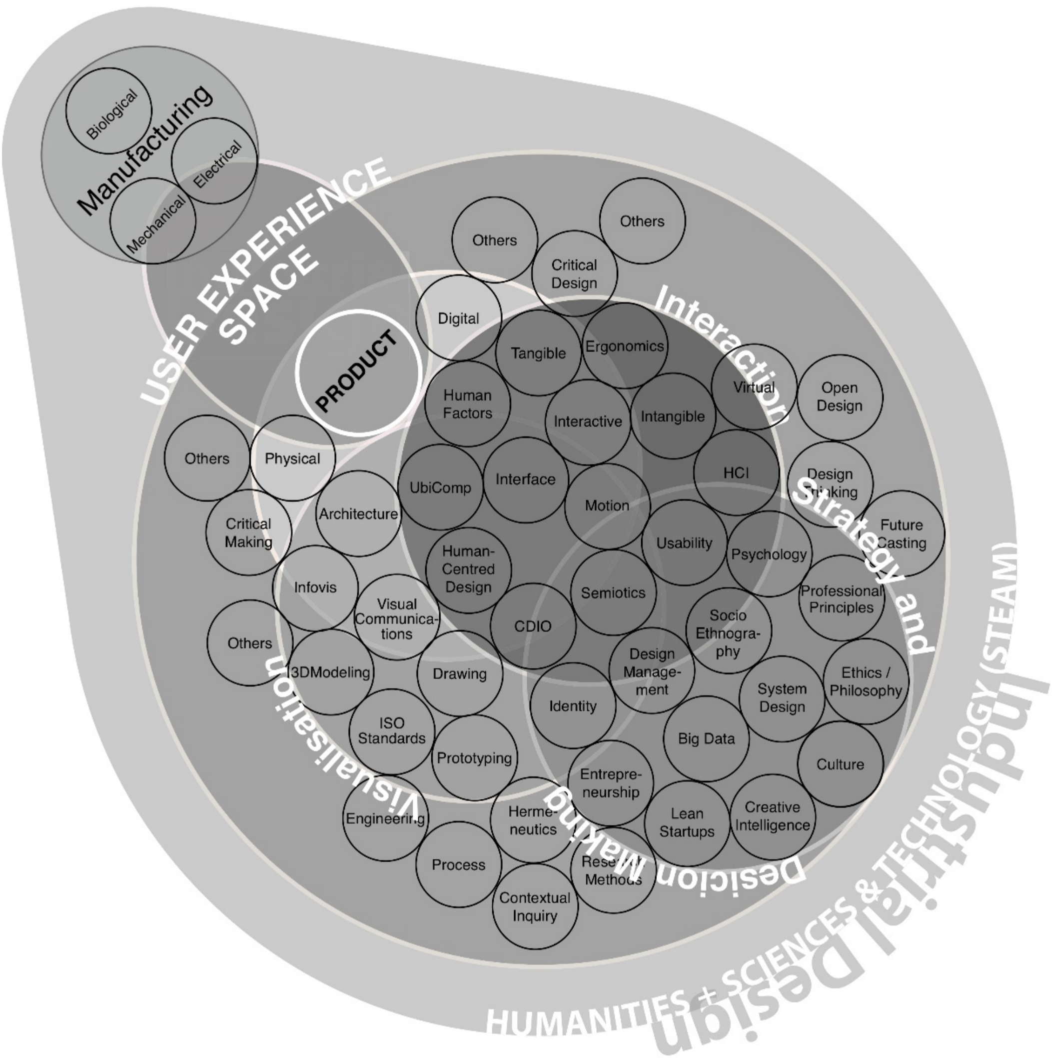



***Figure 15: Competencies envelopes and spaces of coexistence. Reprinted from Author, 27 October 2014, Industrial Design Curriculum 2016: New Vision and Imperative, Unpublished internal document.***

***Table 9: Competencies and intelligence mapping***

| Degree | Level | Year (Autumn, Spring) | Evolutionary Focus: 5 P's (Novoa 2012) | Pedagogy | Mode | Skill Acquisition (Dreyfus & Dreyfus 1986, 2001, 2008) | Competency Centered Learning (TU/e 200??) | Literacy | Linguistics | Narrative | Design | Creativity | Organizational Management | Entrepreneurship |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DOUBLE DEGREE | | | Philosophy | | | Ability | | Creative and Design Intelligence | | | | | | |
| | | | Diagnosis | | | Naive (Aptitude) | | | | | | | | |
| | BACHELOR | 1A | Product | Pedagogy | Transmission | Novice | Awareness | Foundation | Form Patterns (Morphology) | Linear Literal Denotative Analytical | Empathy Operational | Preparation | Functional | Discovery Experiencing |
| | | 1S | Product Process | | | Advanced Beginner | | | | | | Incubation | Balanced Matrix | Concept Development |
| | | | Diagnosis | | | | | | | | | | | |
| | | 2A | Process | Andragogy | Transaction | Competent | Depth | Immersion | Sequences Structure (Syntax) | Procedural Methodical Interactive | Functional Symbolic | | | |
| | | 2S | Process People | | | | | | | | | Insight | Project Matrix | Resourcing |
| | | | Diagnosis | | | | | | | | | | | |
| | | 3A | People | Heutagogy | Transformation | Proficient | | | | | | Evaluation | | Actualization |
| | | 3S | People Places | Paragogy | | Expert | Expertise | Integration Consolidation | Connections Meanings (Semantics) | Systemic Modeling Experiential | Contextual Cultural Collective Networked | Elaboration Disruption Originality | Venture Autonomous Startups | Harvesting |
| | | | Diagnosis | | | | | | | | | | | |
| | | 4A | Places | | | Mastery | | | | | | | | |
| | | | Diagnosis | | | | | | | | | | | |
| | | 4S | Philosophy Product Process People Places | | Generation | Practical Wisdom | Visionary | Fluency | | Multidirectional Multimodal Figurative Connotative Synthetic Distributed | | | | |
| | | | Diagnosis | | | | | | | | | | | |
| | | 5A | DOUBLE DEGREE | | | | | | | | | | | |
| | | 5S | | | | | | | | | | | | |
| | MASTERS | 6A | Philosophy Product Process People Places | Heutagogy Paragogy | Transformation / Generation | Expert | Expertise | Integration | Cultural Context Significance | Multidirectional Multimodal Figurative Connotative Synthetic Distributed | Contextual Cultural Collective Networked | Preparation Incubation | Venture Autonomous Startups | Resourcing |
| | | 6S | | | | Mastery | | Consolidation | | | | Insight Evaluation | | Actualization |
| | | 7A | | | | Practical Wisdom | Visionary | | | | | | | |
| | | 7S | | | | | | Fluency | | | | Elaboration Disruption Originality | | Harvesting |

*Note*. Reprinted from Author, 27 October 2014, *Industrial Design Curriculum 2016: New Vision and Imperative*, Unpublished internal document.

## Discussion

This article has described a three-year research project towards a new industrial design program launched in 2016. A new curriculum needed to consider cultural and historical constraints and potential, while capitalising on designers' and learners' adaptable and elastic minds. It also had to reconnect new forms of education and professional practice with its discipline heritage. *Redesigning* came to place with the realisation that successful design education should not only be about showing how to create physical objects for mass production in an input-output economy. In this new 21st century era, education should go beyond, into learning critically about a society characterised by highly interconnected sociotechnical and organisational networks within a creative and knowledge-based economy.

This repositioning of education allowed a new perspective from which to answer queries about whether an industrial design curriculum was capable of enabling a transformative design-driven innovation culture. This was especially pertinent when a transmission teaching model was the starting point and participants seemed in disadvantage comparing with international benchmarks. Findings showed successful local design learning was possible if the focus was changed to:

- Outcomes accomplished by stakeholders (users, learners, institutions, designers and academics) *instantiation.*
- Redefining design artefacts as epistemic instruments in the form of digital-physical platforms and projects that seek to address matters-of-concern, human activities and ecosystems
- Users' experience based on activity mediated by artefacts, their relationships and contradictions.
- Collaborative communities that emerge by co-creating values as *knots* in a grid of interactions and *runaway objects*.

***Figure 16: Children car safety design-driven innovation through physical-digital industrial and HCI design intelligence. Reprinted from Mubin, O., Novoa, M., Ferguson, J., & Taylor, J. (2014), Leveraging the design of child restraint systems to reduce driver distraction, In***

***Proceedings of the 32nd annual ACM Conference on Human factors in Computing Systems (pp. 1771-1776): ACM.***

Fittingly, the new program assisted students' cultural-historical development along the lines of a proposed industrial design history evolution (Product-Production, Process-Method, People-Participation, Place-Time-Practice). A constructivist and constructionist strategy were implemented to transition towards and align with international benchmarks that were based on empathic, exploratory and experimental *liquid-centre* learning models welcoming of other disciplines and users' *real particulars.* Significantly, from the first year, the curriculum was inverted to learn through and by *applied research* and *critical making*. Similarly, incorporation with outside user and industry communities was set to progress from industry coaching to final year Design Factory-like projects with a *work integrated learning* approach. Initial uncertainty was overcome by collaborative construction of knowledge that transformed participants from technology consumers to active cultural producers and mediators for social benefit. This opened the course to envisioning future human and industrial digital-physical iterations, space and time narratives, cyber-culture, 4.0 industrial revolution's automation, generative design and artificial intelligence.

Research results also helped the proposal that digitalisation could enhance, but not replace, many physical heuristic project-based forms of learning. A new curriculum had to address digital benefits and constraints. Used properly, digitality would assist learning, high-level thinking and reasoning to convert design into cultural, aesthetic and form intelligence. As a case in point, students intending to undertake fourth year Honours appreciated the ePortfolio process and methodology instilled in them. Similarly, those transferring to their teaching degree said ePortfolio was valuable and they would intend using it when teaching professionally. Furthermore, contributions from students indicated industrial design education should expand into digital materiality since 21st century knowledge flows are accelerating the discipline into the notion of living in a digitalised culture that blurs the physical and digital divide. Millennials and GenZ participants (students) did not make a big distinction between this divide when compared to Generation X and Baby Boomers (academics and other staff).

Remarkably, digital materiality borrows definitions, principles and properties from physical materiality to justify its existence and integrate design process (Leonardi, 2010; Negroponte, 1996; S. Pink, Ardèvol, & Lanzeni, 2016). This presents a new challenge for design and its education that now compete against contenders crossing over from other knowledge-based fields. Adversaries come from markets with the force of co-makers, open source technology communities, hackers, crowd-sourced ideas, subversive innovation, crypto-currencies, and new nature. People are considered products and platforms while patents are old-fashioned and design stars are no longer worshipped (Ardern & Jain, 2015; Jain, 2013, 2015).

A *constructivist*, *constructionist* and *critical design* curriculum offers a transformation pathway to design education still embedded within conservative institutional legacies. It greatly depends on customised and staged change, continuity of leadership, vision, and keeping true to new design artefact values. Similar to any design artefact, course success will be proven at the point of everyday *instantiation* by interaction amid users, users and artefacts, and between artefacts. Design learning is no longer about *affirmative design*.

Instead, it needs to assist academic, industrial and social change through design research and innovation-driven practice within physical-digital coexisting *spaces of being*.

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## References

Aalto University. (2008). Aalto Design Factory | Love for Business, Design and Engineering. Retrieved from https://designfactory.aalto.fi/

Aicher, Olt. (1919). The Bauhaus and Ulm. In Philipp Oswalt & Melissa Thoroson Hause (Eds.), *Bauhaus Conflicts 1919 -2009* (Vol. 2009, pp. 174-186). Ostfildern, Germany: Hatje Cantz.

Aicher, Otto. (1994). *World As Design: Writings of Design*: John Wiley & Sons.

Ainley, John, & Gebhardt, Eveline. (2013). *Measure for Measure: A Review of Outcomes of School Education in Australia.* Melbourne: ACER.

Alberto, Paul A, & Troutman, Anne C. (2012). *Applied Behavior Analysis for Teachers*: Pearson Higher Ed.

Allen, S. (2015). *The Hyper-Connected Workforce.* Harvard Business School Publishing (Ed.) Retrieved from https://hbr.org/sponsored/2016/04/the-hyper-connected-workforce

Amit, Gadi. (2010). American Design Schools are a Mess, and Produce Weak Graduates. *Fast Company, retrieved from* *http://www.fastcodesign.com/1662634/americandesignschools-are-a-mess-and-produce-weak-graduates*.

Andersen, Lisa, Ashton, Paul, & Colley, Lisa. (2015). *Creative Business in Australia Learnings from the Creative Industries Innovation Centre, 2009 to 2015*. Sydney, Australia: UTS ePrint.

Anderson, Lorin W, Krathwohl, David R, Airasian, P, Cruikshank, K, Mayer, R, Pintrich, P, Wittrock, M. (2001). A Taxonomy for Learning, Teaching and Assessing: A Revision of Bloom's Taxonomy. *New York. Longman Publishing. Artz, AF, & Armour-Thomas, E.(1992). Development of a Cognitive-Metacognitive Framework for Protocol Analysis of Mathematical Problem Solving inSmall Groups. Cognition and Instruction, 9*(2), 137-175.

Antonelli, Paola. (2008). *Design and the Elastic Mind*. New York, N.Y.: The Museum of Modern Art.

Archer, Bruce, Baynes, Ken, & Roberts, Phil. (1992). *The Nature of Research into Design and Technology Education*. U.K.: Loughborough University of Technology, Department of Design and Technology.

Archer, Bruce, Baynes, Ken, & Roberts, Phil. (2005). A framework for Design and Design Education. *Wellesbourne, UK: The Design and Technology Association*.

Ardern, Jon, & Jain, Anab. (2015). Superflux. *Ubiquity: The Journal of Pervasive Media, 4*(1-2), 69-74.

Armengaud, J. E. (1853). The Practical Draughtsman's Book of Industrial Design, giving a Complete Course of Mechanical Engineering and Architectural Drawing (pp. 423-423). London: J. Frances, etc.

Australian Bureau of Statistics. (2013). 5271.0.55.001 - Discussion Paper: Cultural and Creative Activity Satellite Accounts, Australia. *Commonwealth of Australia.* Retrieved from http://www.abs.gov.au/ausstats/abs@.nsf/Latestproducts/5271.0.55.001Main%20Features52013?opendocument&tabname=Summary&prodno=5271.0.55.001&issue=2013&num=&view=

Australian Bureau of Statistics. (2015). Unit Group 2323 Fashion, Industrial and Jewellery Designers. *Commonwealth of Australia.* Retrieved from http://www.abs.gov.au/ausstats/abs@.nsf/Product+Lookup/1220.0~First+Edition,+Revision+1~Chapter~UNIT+GROUP+2323+Fashion,%20Industrial%20and%20Jewellery%20Designers

Australian Bureau of Statistics. (2017). 8155.0 - Australian Industry, 2015-16. *Commonwealth of Australia.* Retrieved from http://www.abs.gov.au/ausstats/abs@.nsf/DetailsPage/8155.02015-16/

Australian Industry Group. (2015). *Progressing STEM Skills in Australia.* AIGroup (Ed.) Retrieved from http://cdn.aigroup.com.au/Reports/2015/14571_STEM_Skills_Report_Final_-.pdf

BachelorsPortal. (2017). Industrial Design Bachelor's Degrees in Australia. from StudyPortals https://www.bachelorsportal.com/study-options/271745077/industrial-design-australia.html

Bergdoll, Barry, & Dickerman, Leah. (2009). *Bauhaus 1919-1933: Workshops for Modernity*: The Museum of Modern Art, New York; 1st Edition.

Bettinger, Eric, & Loeb, Susanna. (2017). *Promises and Pitfalls of Online Education*. Retrieved from www.brookings.edu/wp-content/uploads/2017/06/ccf_20170609_loeb_evidence_speaks1.pdf

Betts, Paul. (2004). *The Authority of Everyday Objects: A Cultural History of West German Industrial Design* (Vol. 34): Univ of California Press.

Black, Elizabeth, & Rankine, Leanne. (2013). *Pilot Evaluation Report - PebblePad, Part 1.* University of Western Sydney (Ed.)  Retrieved from Internal document (previously available in university website)

Blom, Diana, Rowley, Jennifer, Bennett, Dawn, Hitchcock, Matthew, & Dunbar-Hall, Peter. (2013). *Two-Way Impact: Institutional E-Learning Policy/Educator Practices in Creative Arts through ePortfolio Creation*. Paper presented at the Proceedings of the 12th European conference on e-Learning, Sophia Antipolis, France.

Bloom, Benjamin S, Engelhart, Max D, Furst, Edward J, Hill, Walker H, & Krathwohl, David R. (1956). Taxonomy of Educational Objectives: The Classification of Educational Goals. Handbook I: Cognitive Domain. New York: David McKay Company. *Inc.(7th Edition 1972)*.

Bonsiepe, Gui. (2010). *Design and democracy*: Bedford Press.

Bourdieu, Pierre. (1984). *Distinction: A Social Critique of the Judgement of Taste*. Cambridge MA: Harvard University Press.

Bourdieu, Pierre. (1990). *The Logic of Practice*: Stanford Univ Pr.

Bourdieu, Pierre, & Biggart, Nicole Woolsey. (2002). The Forms of Capital. *Readings in Economic Sociology*, pp. 280-291.

Bourdieu, Pierre, & Passeron, Jean Claude. (1990). *Reproduction in Education, Society, and Culture* (Vol. 4): Sage Publications Ltd.

Brand, Reon, & Rocchi, Simona. (2011). *Rethinking Value in a Changing Landscape: A Model for Strategic Reflection and Business Transformation*. Retrieved from http://www.design.philips.com/philips/shared/assets/design_assets/pdf/nvbD/april2011/paradigms.pdf

Bremner, Craig, & Rodgers, Paul. (2013). Design Without Discipline. *Design Issues, 29*(3), 4-13.

Brown, John Seely. (2013). Learning in and for the 21st Century. In CJ Koh No (Ed.), *Professorial Lecture Series*. Singapore: National Institute of Education.

Cahill, Lisa. (2010). *Australian Design Alliance Launch Event Report*. Retrieved from http://australiandesignalliance.com/publication/ada-launch-report-pdf/

Carneiro, Roberto. (2011). Discovering the Treasure of Learning. In Jin Yang (Ed.), *Conceptual evolution and policy developments in lifelong learning*. Hamburg: Unesco Institute for Lifelong Learning.

Carr, Nicholas. (2011). *The Shallows: What the Internet Is Doing to Our Brains*: WW Norton & Company.

Centre for Western Sydney. (2017). *Data and Visualisations - Western Sydney University*. Retrieved from: https://www.westernsydney.edu.au/cws/gws_research

Chen, Baiyun, Seilhamer, Ryan, Bennett, Luke, & Bauer, Sue. (2015). Students' Mobile Learning Practices in Higher Education: A Multi-Year Study. *Educause Review, 7*.

Christensen, Clayton M, & Eyring, Henry J. (2011). *The Innovative University: Changing the DNA of Higher Education from the Inside Out*: John Wiley & Sons.

Cormack. (2013 - 2015). Home | Cormack Innovation Awards. Retrieved from http://cormackia.com.au/?page_id=48

Corneli, Joseph, & Danoff, Charles Jeffrey. (2011). Paragogy: Synergizing Individual and Organizational Learning. *Wikiversity,*(Creative Commons Attribution/Share-Alike License), Cit, 33.

Corneli, Joseph, Danoff, Charles Jeffrey, Pierce, Charlotte, Ricaurte, Paola, & Macdonald, Lisa Snow. (2015). *Patterns of Peeragogy.* Paper presented at the Proceedings of the 22nd Conference on Pattern Languages of Programs.

Cox, George. (2005). *Cox Review of Creativity in Business: Building on the UK's Strengths*. Crown HM Treasury. U.K. (Ed.) Retrieved from http://webarchive.nationalarchives.gov.uk/20080910135408/http://www.hm-treasury.gov.uk/independent_reviews/cox_review/coxreview_index.cfm

Creative Industries Innovation Centre. (2015). *Valuing Australia's Creative Industries: Final Report. A report prepared by SGS Economics & Planning for Creative Industries Innovation Centre, Sydney*. Retrieved from https://opus.lib.uts.edu.au/handle/10453/34865

Cross, Nigel. (1982). Designerly Ways of Knowing. *Design Studies, 3*(4), 221-227.

Cross, Nigel. (1993). A History of Design Methodology *Design Methodology and Relationships with Science* (pp. 15-27): Springer.

Cross, Nigel. (2001). Designerly Ways of Knowing: Design Discipline versus Design Science. *Design Issues, 17*(3), 49-55.

Cross, Nigel. (2007). From a Design Science to a Design Discipline: Understanding Designerly Ways of Knowing and Thinking. *Design research now*, 41-54.

Cruickshank, Mr Leon. (2014). *Open Design and Innovation: Facilitating Creativity in Everyone*: Gower Publishing, Ltd.

Cully, Mark. (2016). *Australian Industry Report 2016.* Retrieved from https://industry.gov.au/Office-of-the-Chief-Economist/Publications/AustralianIndustryReport/index.html

Deloitte. (2015). Industrial & Product Design. *Data USA*.

Deloitte Touche Tohmatsu. (2017). *The 2017 Deloitte Millennial Survey : Apprehensive Millennials - Seeking Stability and Opportunities in an Uncertain World*: Deloitte Touche Tohmatsu Limited.

Design Council, U.K. (2005). The Business of Design: Design Industry Research in 2005. The Design Council: London.

Design Future Council. (2009). *Design Intelligence : America's Best Architecture and Design Schools* (9780996440189). Retrieved from Norcross, GA: https://books.google.com.au/books?id=deEwngAACAAJ

Design Future Council. (2013). *Design Intelligence : America's Best Architecture and Design Schools* (9780996440189). Retrieved from Norcross, GA: https://books.google.com.au/books?id=deEwngAACAAJ

Design Future Council. (2014). *Design Intelligence : America's Best Architecture and Design Schools* (9780996440189). Retrieved from Norcross, GA: https://books.google.com.au/books?id=deEwngAACAAJ

Design Future Council. (2016). *Design Intelligence : America's Best Architecture and Design Schools* (9780996440189). Retrieved from Norcross, GA: https://books.google.com.au/books?id=deEwngAACAAJ

Dewey, John. (1902). *The Child and the Curriculum*: Chicago: University of Chicago Press.

Dewey, John. (1975). *Democracy and Education: An Introduction to the Philosophy of Education*: Free Press New York.

Dixon, Tim. (2013). *NSW Creative Industries Economic Profile* (ISBN 978-1-742565212). Retrieved from https://opus.lib.uts.edu.au/bitstream/10453/46904/1/Creative-Industries-Economic-Profile.pdf

Dondis, Donis A. (1973). *A Primer of Visual Literacy*. Cambridge, Mass.: Cambridge, Mass. : MIT Press.

Dorst, Kees. (1997). *Describing Design: A Comparison of Paradigms*: Technische Universiteit Delft.

Dorst, Kees, & Dijkhuis, Judith. (1995). Comparing Paradigms for Describing Design Activity. *Design Studies, 16*(2), 261-274.

Dos Santos Duisenberg, Edna. (2010). Creative Economy Report 2010. Creative Economy: A Feasible Development Option: UNCTAD United Nations, Geneva.

Dreyfus, S. E., & Dreyfus, H. L. (1980). A Five-Stage Model of the Mental Activities Involved in Directed Skill Acquisition: Storming Media.

Drucker, Peter F. (1999). Knowledge-Worker Productivity: The Biggest Challenge. *The Knowledge Management Yearbook 2000-2001*.

Drucker, Peter F. (2011). *Landmarks of Tomorrow: A Report on the New*: Transaction Publishers.

Dunne, Anthony. (1999). *Hertzian Tales: Electronic Products, Aesthetic Experience and Critical Design*: Art Books Intl Ltd.

Dunne, Anthony, & Raby, Fiona. (2001). *Design Noir: The Secret Life of Electronic Objects*: Springer Science & Business Media.

Ehn, Pelle. (1998). Manifesto for a Digital Bauhaus 1. *Digital Creativity, 9*(4), 207-217.

Engeström, Yrjö. (1987). The Emergence of Learning Activity as a Historical Form of Human Learning, Learning by Expanding: An Activity-Theoretical Approach to Developmental Research. *Orienta-Konsultit Oy*, 29 - 127.

Engeström, Yrjö. (1990). *Learning, Working and Imagining: Twelve Studies in Activity Theory*: Orienta-konsultit.

Engeström, Yrjö. (2001). Expansive Learning at Work: Toward an Activity Theoretical Reconceptualization. *Journal of Education and Work, 14*, 133-156. doi:10.1080/13639080020028747

Engeström, Yrjö. (2008). *From Teams to Knots: Activity-Theoretical Studies of Collaboration and Learning at Work*: Cambridge University Press.

Engeström, Yrjö. (2009a). The Future of Activity Theory: A Rough Draft. *Learning and Expanding with Activity Theory*, 303-328.

Engeström, Yrjö. (2009b). Wildfire Activities: New Patterns of Mobility and Learning. *International Journal of Mobile and Blended Learning (IJMBL), 1*(2), 1-18.

Engeström, Yrjö. (2013). From Communities of Practice to Mycorrhizae. *Communities of Practice* (pp. 51-64): Routledge.

Engeström, Yrjö. (2014). *Learning by Expanding*: Cambridge University Press.

Engeström, Yrjö, & Sannino, Annalisa. (2010). Studies of Expansive Learning: Foundations, Findings and Future Challenges. *Educational Research Review, 5*(1), 1-24.

Fallan, Kjetil. (2010). *Design History: Understanding Theory and Method*: Berg.

Freire, Paulo. (1970). Pedagogy of the Oppressed, trans. *Myra Bergman Ramos. New York: Continuum*, 65-80.

Gallie, Walter Bryce. (1955). *Essentially Contested Concepts.* Paper presented at the Proceedings of the Aristotelian Society.

Gausby, Alyson. (2015). Attention Spans. Consumer Insights. *Microsoft Canada*.

Gedenryd, Henrik. (1998). *How Designers Work-Making Sense of Authentic Cognitive Activities* (Vol. 75): Cognitive Science.

Gibson, James J. (2014). *The Ecological Approach to Visual Perception: Classic Edition*: Psychology Press.

Gleeson, Jim. (2013). The European Credit Transfer System and Curriculum Design: Product before Process? *Studies in Higher Education, 38*(6), 921-938.

Gorman, Carma. (2003). *The industrial design reader*: Skyhorse Publishing Inc.

Graphiq. (2017). Best College Comparison - Rankings, Degrees & Reviews. *StartClass.* Retrieved from http://colleges.startclass.com/?launch_filters=%5B%7B%22field%22%3A%22cipcode_clone_app_data_filter%22%2C%22operator%22%3A%22%3D%22%2C%22value%22%3A%2250.0404%22%7D%5D

Gropius, Walter. (1919). *Bauhaus Manifesto and Program*. Weimar: The Administration of the Staatliche Bauhaus.

Guyotte, Kelly W, Sochacka, Nicki W, Costantino, Tracie E, Walther, Joachim, & Kellam, Nadia N. (2014). STEAM as social practice: Cultivating creativity in transdisciplinary spaces. *Art Education, 67*(6), 12-19.

Guyotte, Kelly W, Sochacka, Nicola W, Costantino, Tracie E, Kellam, Nadia N, & Walther, Joachim. (2015). Collaborative creativity in STEAM: Narratives of art education students' experiences in transdisciplinary spaces. *International journal of education & the arts, 16*(15).

Habermas, Jürgen. (2012). Modernity: An Unfinished Project [1980]. *Contemporary Sociological Theory*, 444.

Harel, Idit Ed, & Papert, Seymour Ed. (1991). *Constructionism*: Ablex Publishing.

Harvey, Andrew. (2016, 17 June 2016). Uncapping of University Places Achieved What it Set Out to Do. So Why Is It Dubbed a Policy Failure? *The Conversation.* Retrieved from http://theconversation.com/uncapping-of-university-places-achieved-what-it-set-out-to-do-so-why-is-it-dubbed-a-policy-failure-61082

Hase, Stewart, & Kenyon, Chris. (2013). *Self-Determined Learning: Heutagogy in Action*: A&C Black.

Heidegger, Martin. (1962). *Being and Time*: Harper Collins, San Francisco.

Herbart, Johann Friedrich. (1806). *Allgemeine Pädagogik: Aus dem Zweck der Erziehung abgeleitet*: JF Röwer.

Horkheimer, Max, Adorno, Theodor W, & Noeri, Gunzelin. (2002). *Dialectic of enlightenment*: Stanford University Press.

HotCourses. (2017a). Australian Institutions Offering Industrial Design Courses. Retrieved from https://www.hotcoursesabroad.com/study/training-degrees/australia/industrial-design-courses/loc/9/cgory/f10-3/sin/ct/programs.html

HotCourses. (2017b, 2017). Australian Institutions Offering Industrial Design Masters Degrees Courses. Retrieved from https://www.hotcoursesabroad.com/study/training-degrees/australia/masters/industrial-design-courses/loc/9/slevel/57-3-3/cgory/f10-3/sin/ct/programs.html

HotCourses. (2017c). Industrial Design Courses at University of Technology Sydney - UTS.

HotCourses. (2017d). Institutions in Australia Offering Postgraduate Industrial Design Courses. Retrieved from https://www.hotcoursesabroad.com/study/training-degrees/australia/postgraduate/industrial-design-courses/loc/9/slevel/3/cgory/f10-3/sin/ct/programs.html

Howkings, J. (2001). *The Creative Economy–How People Make Money from their Ideas*: The Penguin Press. Allen Lane.

Hustwit, Gary, Beshenkovsky, Joe, Geissbuhler, Luke, & Dunne, Kristian. (2009). Objectified. London, UK: Swiss Dots Limited.

Industrial Designers Society of America. (2014, 2014/10/03). ID Schools. *Industrial Designers Society of America - IDSA.* Retrieved from http://www.idsa.org/education/id-schools

Innovation and Science Australia. (2017). *Performance Review of the Australian Innovation, Science and Research System 2016*: Australian Government - Department of Industry and Science.

Irwin, Terry. (2015). Redesigning a Design Program: How Carnegie Mellon University is Developing a Design Curricula for the 21st Century. *Solutions, January-February 2015*, 91-100.

Irwin, Terry, Tonkinwise, Cameron, & Kossoff, Gideon. (2013). *Transition Design: Re-conceptualizing Whole Lifestyles.* Paper presented at the Head, Heart, Hand: AIGA Design Conference.

Jacob, Sam. (2013). One of the Culprits behind Prism? Design thinking (Really). *Wired.* Retrieved from https://www.wired.com/2013/06/the-real-culprit-behind-prism-design-thinking-yes/

Jain, Anab. (2013). *Design for the New Normal*. Paper presented at the Next Conference, Berlin. https://www.youtube.com/watch?v=QaL80fzcan8

Jain, Anab. (2015). Superflux - Translating Future Uncertainty into Present Day Choices. Retrieved from http://superflux.in/

Kapp, Alexander. (1833). *Platon's Erziehungslehre, als Pädagogik für die Einzelnen und als Staatspädagogik. Oder Dessen Praktische Philosophie aus den Quellen Dargestellt von Alexander Kapp*: F. Essmann.

Kaptelinin, Victor. (2013). Activity Theory. In Mads Soegaard & Rikke Friis Dam (Eds.), *The Encyclopedia of Human-Computer Interaction, 2nd Ed* (2nd Ed ed.): The Interaction Design Fundation. Chr. Molbechs Vej 4 DK-8000 Aarhus C. Denmark.

Kenyon, Chris, & Hase, Stewart. (2001). Moving from Andragogy to Heutagogy in Vocational Education.

Khayyat, Mashael. (2016). A Proposed Model for the Fourth Generation of Activity Theory to be Applied on the Smart City Research.

Kirkpatrick, Denise. (2017). *Learning and Teaching: Digital Strategies and Enabled Environments*. Paper presented at the University of Canterbury's Teaching Week Christchurch, New Zealand.

Knowles, Malcolm. (1980). What is Andragogy. *The Modern Practice of Adult Education, from Pedagogy to Andragogy*, 40-62.

Krippendorff, Klaus. (2005). *The Semantic Turn: A New Foundation for Design*: crc Press.

Krippendorff, Klaus. (2008). Designing in Ulm and off Ulm. In K-A. Czemper (Ed.), *HfG, Ulm; Die Abteilung Produktgestaltung* (pp. 55 - 72). Dortmund, Germany: Verlag Dorothea Rohn.

Kuutti, Kari. (2005). *Defining an Object of Design by the Means of the Cultural-Historical Activity Theory.* Paper presented at the Conference Proceedings (CD-ROM) by University of Arts Bremen.

Labour Market Information Portal. (2017). Employment Projections. Retrieved from ttp://lmip.gov.au/default.aspx?LMIP/EmploymentProjections

Latour, Bruno. (2004). Why Has Critique Run out of Steam? From Matters of Fact to Matters of Concern. *Critical inquiry, 30*(2), 225-248.

Latour, Bruno. (2008). *A Cautious Prometheus? A Few Steps toward a Philosophy of Design (with Special Attention to Peter Sloterdijk).* Paper presented at the Proceedings of the 2008 annual international conference of the design history society.

Latour, Bruno. (2009). Spheres and Networks. Two Ways to Reinterpret Globalization. *Harvard Design Magazine*(30), 138-144.

Leonardi, Paul M. (2010). Digital Materiality? How Artifacts without Matter, Matter. *First Monday, 15*(6).

Lessig, Lawrence. (2008). *Remix : Making Art and Commerce Thrive in the Hybrid Economy*. New York: New York : Penguin Press.

Liem, André, & Sigurjonsson, Johannes B. (2014). Positioning Industrial Design Education within Higher Education: How to face increasingly challenging market forces? *Uniped, 1*, 44-57.

Lockwood, Thomas. (2010). *Design Thinking: Integrating Innovation, Customer Experience, and Brand Value*: Skyhorse Publishing, Inc.

Lyotard, Jean-François. (1984). *The Postmodern Condition: A Report on Knowledge* (Vol. 10): U of Minnesota Press.

Maciuika, John V. (2005). *Before the Bauhaus: Architecture, Politics, and the German State, 1890-1920* (Vol. 2): Cambridge University Press.

Maeda, John. (2012). STEM to STEAM: Art in K-12 is Key to Building a Dtrong Economy. *Edutopia: What works in education*.

Maier, Jonathan RA, & Fadel, Georges M. (2001). *Affordance: The Fundamental Concept in Engineering Design.* Paper presented at the Proceedings of ASME Design Theory and Methodology Conference, Pittsburgh, PA. Paper no. DETC2001/DTM-21700.

Maier, Jonathan RA, & Fadel, Georges M. (2009). Affordance Based Design: A Relational Theory for Design. *Research in Engineering Design, 20*(1), 13-27.

Majorek, Czeslaw. (1998). The Interpretation of Herbartian Pedagogics in the 19th Century Polish Teacher Training Seminars. *Paedagogica Historica, 34*(sup1), 471-481.

Maldonado, Tomás. (1958). New Developments in Industry and the Training of Designers. *Ulm 2*. Germany: Ulm School of Design (Hochschule für Gestaltung – HfG).

Maldonado, Tomás. (1972). Revolution: Toward a Critical Ecology, trans. Mario Domandi. *New York: Harper and Row, 60*(Design, Nature), 65.

Martin, Roger L. (2007). *The Opposable Mind : How Successful Leaders Win through Integrative Thinking*. Boston, Mass.: Boston, Mass. : Harvard Business School Press.

Mason, Glenn, Langendyk, Vicki, & Wang, Shaoyu. (2013). *The Introduction of an Online Portfolio System in a Medical School: What Can Activity Theory Tell Us?* Paper presented at the ASCILITE-Australian Society for Computers in Learning in Tertiary Education Annual Conference.

Miller, Daniel, & Tilley, Christopher Y. (1984). *Ideology, Power and Prehistory*: Cambridge University Press.

Mubin, Omar, Novoa, Mauricio, Ferguson, Joel, & Taylor, Joel. (2014). *Leveraging the Design of Child Restraint Systems to Reduce Driver Distraction.* Paper presented at the CHI'14 Extended Abstracts on Human Factors in Computing Systems.

Negroponte, Nicholas. (1996). *Being Digital*: Vintage.

Nelson, Harold G. (2012). *The Design Way : Intentional Change in an Unpredictable World* (Second edition. ed.). Cambridge, Massachusetts: MIT Press.

Norman, Donald A. (1999). Affordance, Conventions, and Design. *Interactions, 6*(3), 38-43.

Norman, Donald A. (2010). Why Design Education Must Change-Core77. *Design Magazine and Resource*.

Norman, Donald A. (2013). *The Design of Everyday Things: Revised and Expanded Edition*: Basic Books (AZ).

Norman, Donald A. (2015). The Future of Design: When You Come to a Fork in the Road, Take It. *December.* Retrieved from https://www.jnd.org/dn.mss/the_future_of_design.html

Novoa, Mauricio. (2012). *Vision for Industrial Design Course: Presentation to Directors of Academics Program Panel*. Retrieved from Unpublished internal document:

Novoa, Mauricio. (2014). *Industrial Design Curriculum 2016: New Vision and Imperatives for the New Normal of Innovation and its Education*. Retrieved from Unpublished internal document:

Nussbaum, Bruce. (2013). *Creative Intelligence: Harnessing the Power to Create, Connect, and Inspire*. New York, N.Y.: Harper Business.

Oswald, David. (2012). The Information Department at the Ulm School of Design. *Blucher Design Proceedings, 1*(1), 46-50.

Overbeeke, Kees , & Hummels, Caroline (2014). *Industrial Design*. Aarhus, Denmark: The Interaction Design Foundation.

Papert, Seymour. (1986). *Constructionism: A New Opportunity for Elementary Science Education*: Massachusetts Institute of Technology, Media Laboratory, Epistemology and Learning Group.

PayScale. (2017, 2017). Industrial Designer Salary. *PayScale Human Capital.* Retrieved from http://www.payscale.com/research/US/Job=Industrial_Designer/Salary

Pink, Daniel H. (2006). *A Whole New Mind: Why Right-Brainers will Rule the Future*: Penguin.

Pink, Sarah, Ardèvol, Elisenda, & Lanzeni, Débora. (2016). *Digital Materialities: Design and Anthropology*: Bloomsbury Publishing.

Pope, Richard. (2016). *Power, Design and Possibilities: Designing Digital Services that Are Accountable, Understood, and Trusted*. Paper presented at the OSCON 2016 https://conferences.oreilly.com/oscon/open-source-eu/public/schedule/detail/53909

Q. S. Top Universities. (2016). QS World University Rankings by Subject 2016 - Art & Design. *QS Top Universities.* Retrieved from https://www.topuniversities.com/university-rankings/university-subject-rankings/2016/art-design

Q. S. Top Universities. (2017). QS World Universities by Ranking: Art & Design. *Top Universities.* Retrieved from https://www.topuniversities.com/university-rankings/university-subject-rankings/2017/art-design#sorting=rank+region=+country=+faculty=+stars=false+search=

Ratto, Matt, Atkinson, P, Avital, M, Mau, B, Ramakers, R, & Hummels, C. (2011). Open Design and Critical Making. *Open Design Now: Why Design Cannot Remain Exclusive. Amsterdam: BIS Publishers. URL: http://opendesignnow.org*.

Ratto, Matt, & Hockema, Stephen. (2009). Flwr Pwr: Tending the Walled Garden. *Walled Garden. Virtueel Platform Amsterdam, The Netherlands*, 51-60.

Roberston, David. (2013a). *Australian Design 2013. Issues & Concerns in the Design Professions. PN 034 Issue B*. Retrieved from https://www.design.org.au/documents/item/127

Roberston, David. (2013b). *Design Sector Statistics. Design General. PN 033 Issue A*. Retrieved from https://www.design.org.au/documents/item/126

Roos, Göran. (2012). *Manufacturing into the Future*. Government of South Australia Retrieved from http://www.makingmarion.com.au/4880/documents/11779/download.

Roos, Johan, & Victor, Bart. (1998). In Search Of Original Strategies: How About Some Serious Play. *IMD Perspectives for Managers, 56*(15), 1-4.

Roos, Johan, & Victor, Bart. (1999). Towards a new model of strategy-making as serious play. *European Management Journal, 17*(4), 348-355. doi:10.1016/S0263-2373(99)00015-8

Roos, Johan, Victor, Bart, & Statler, Matt. (2004). Playing seriously with strategy. *Long Range Planning, 37*(6), 549-568.

Rowley, Jennifer, Bennett, Dawn, & Blom, Diana. (2014). *ePortfolios in the Teaching of Music and other Creative and Performing Arts in Four Australian Universities.* Paper presented at the Proceedings of the International Society for Music Education: 31st World Conference on Music Education, Porto Alegre, Brazil, 20-25 July 2014.

Russell, Carol. (2014). Herding Cats And Measuring Elephants: Implementing And Evaluating An Institutional Blended And Mobile Learning Strategy. *Rhetoric and Reality: Critical perspectives on educational technology*, 211-221.

Russell, Carol, & Jing, Qi. (2013). *Evaluating an Institutional Blended & Mobile Learning Strategy.* Paper presented at the ASCILITE-Australian Society for Computers in Learning in Tertiary Education Annual Conference.

Saletnik, Jeffrey, & Schuldenfrei, Robin. (2013). *Bauhaus Construct: Fashioning Identity, Discourse and Modernism*: Routledge.

Sannino, Annalisa. (2011). Activity Theory as an Activist and Interventionist Theory. *Theory & Psychology, 21*(5), 571-597.

Seno, Alexandra. (2010). The Future of Industrial Design. Interview with Ron Arad. *Wall Street Journal*.

Simon, Herbert A. (1969). The Sciences of the Artificial. *Cambridge, MA*.

Skinner, BF. (1974). *About Behaviorism*. NY: Alfred A: Knopf.

Sloterdijk, Peter. (2011). *Bubbles: Spheres Volume I: Microspherology*. Cambridge MA: MIT Press.

Somerson, Roseanne, & Hermano, Mara L. (2013). *The Art of Critical Making*. Hoboken, New Jersey.: Wiley, City.

Spinuzzi, Clay. (2012). Working Alone Together: Coworking as Emergent Collaborative Activity. *Journal of Business and Technical Communication, 26*(4), 399-441.

Spinuzzi, Clay. (2015). Toward a Typology of Activities: Understanding Internal Contradictions in Multiperspectival Activities. *Journal of Business and Technical Communication, 29*(1), 3-35.

Stross, Charlie. (2014). YAPC NA Keynote : Programming Perl in 2034. Retrieved from https://www.youtube.com/watch?v=EPQLKTcJ26s

StudyPortals. (2017). Industrial Design Degrees in Australia. Retrieved from https://www.bachelorsportal.com/search/#q=ci-202|di-53|lv-bachelor,preparation&start=0&length=10&order=relevance&direction=desc

Terzidis, Kostas. (2007). The Etymology of Design: Pre-Socratic Perspective. *Design Issues, 23*(4), 69-78. doi:10.1162/desi.2007.23.4.69

Thomas, Douglas, & Brown, John Seely. (2011). *A New Culture of Learning: Cultivating the Imagination for a World of Constant Change* (Vol. 219): CreateSpace Lexington, KY.

Tucci, Christopher, & Peters, Tilo. (2015). *Design and Design Frameworks: Investment in KBC and economic performance* (No. EPFL-CHAPTER-213643). Retrieved from https://www.oecd.org/sti/ieconomy/Chapter6-KBC2-IP.pdf

Twigg, Carol A. (2003). Quality, Cost and Access: The Case for Redesign. *The wired tower: Perspectives on the impact of the internet on higher education*, 111-143.

U.S. Bureau of Labor Statistics. (2017a, 2017). Industrial Designers : Occupational Outlook Handbook. Retrieved from https://www.bls.gov/ooh/arts-and-design/industrial-designers.htm#tab-2

U.S. Bureau of Labor Statistics. (2017b). Industrial Designers : Occupational Outlook Handbook: : U.S. Bureau of Labor Statistics. Retrieved from https://www.bls.gov/ooh/arts-and-design/industrial-designers.htm

U.S. Department of Labor. (2017). 27-1021.00 - Commercial and Industrial Designers. Retrieved from https://www.onetonline.org/link/summary/27-1021.00

University of South Australia. (2017). Study Bachelor of Design (Product Design) at the University of South Australia (UniSA). Information for Australian students. Retrieved from http://study.unisa.edu.au/degrees/51-8817

Wakkary, Ron, Odom, William, Hauser, Sabrina, Hertz, Garnet, & Lin, Henry. (2015). *Material Speculation: Actual Artifacts for Critical Inquiry.* Paper presented at the Proceedings of The Fifth Decennial Aarhus Conference on Critical Alternatives.

Watson, John B. (1913). Psychology as the Behaviorist Views it. *Psychological review, 20*(2), 158.

WDO. (2017a). WDO | About | Definition of Industrial Design. Retrieved from http://wdo.org/about/definition/

WDO. (2017b). WDO | About | Vision and Mission. Retrieved from http://wdo.org/about/vision-mission/

Wenger, Etienne. (1998). *Communities of Practice: Learning, Meaning, and Identity*: Cambridge University Press.

Wright, Natalie, Davis, Rebekah M., & Bucolo, Sam. (2013). *Knowledge Economy Market Development Mapping Study*. Retrieved from

Yamagata-Lynch, Lisa C. (2010). *Activity Systems Analysis Methods*. Boston, MA: Springer US.

Zuidervaart, Lambert. (1993). Adorno's Aesthetic Theory: the redemption of illusion.