Understanding the Processes Behind Student Designing: Cases from Singapore

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Abstract
A common perception of designing is that it represents a highly complex activity that is manageable by only a few. However it has also been argued that all individuals are innately capable of designing. Taking up this latter view, we explored the processes behind student designing in the context of Design and Technology (D&T), a subject taught at the Secondary school level in Singapore. We examined the design journey undertaken by two students to understand what designing is like at their level. Case study methodology was adopted to develop a rich data set emerging from the students' design journals, maps of the students' design process, and interviews with the students and supervising teachers. The findings revealed that these students had innate capacities to design. Although the approach taken by each student differed, as reflected in visual representations reflecting the design process as well as their commentary, each displayed similar forms of design thinking. That is, both students proposed a novel and innovative solution to their design problem and were able to articulate sound reasoning of their design decisions throughout the entire design process. The supervising teachers enacted a more facilitative pedagogy that supported each student's design process; this approach differs from traditional pedagogical practices in Singaporean D&T that can be characterised as model-focused and 'top down' in nature.

Key words
design and technology, student designing, design process, teacher facilitation, designerly thinking, design mode

Introduction

In Singapore, Design and Technology (D&T) is a subject taught at the Secondary school level. The syllabus drawn up by the Ministry of Education (MOE) for D&T recommends a model where

> design is concerned with situations which are primarily centred on meaningfully identified needs, problems, desires, and/or wants calling for solutions that can be realised through manufactured artefacts. The solutions may be arrived at through diverse methods but each will include the statement of a brief, ideation, development and realisation that require conscious efforts in research, investigation and on-going evaluation of information and data collected and decisions made (MOE, 2009, p.4).

Figure 1 shows the graphic representation of this description of the designing process. The model depicts designing as a dynamic act where the student designer goes through specified design stages (problem identification; research; ideation; development and realisation of design solution) to arrive at a design proposal. The double-headed arrows signify the dynamic relationship between the various stages.

As a lecturer in the pre-service and in-service courses at the National Institute of Education (NIE) and with involvement in local D&T events and activities, the first author has met and interacted with many D&T teachers. Through these encounters, she found that D&T teachers commonly perceive that designing is a highly complex activity that is pitched at a level beyond the students' ability to handle. Few teachers seem comfortable with the notion that the natural course of designing is dynamic and iterative, like an "ongoing dialogue between the designer and the object" (MOE, 2009, p. 4). As such, many D&T teachers in Singapore tend to adopt a prescriptive approach in guiding the students' design process, with an emphasis on step by step thinking that leads to accomplishing prescribed outcomes stipulated in the syllabus by the Ministry of Education. With good intentions to guide students through the complex act of designing, many D&T teachers have adapted the model suggested by MOE (see figure 1) into one which ignored the double-headed arrows, but followed the numbered ordering of the design stages in a linear fashion. This linear process begins with students 1) looking at the same problem situation followed by 2) conducting research to gather data on the problem and 3) conceptualising ideas (solutions to the problem) before 4) developing a chosen idea to be 5) realised in the form of an artefact (concrete form).

This view that design should be taught in a guided, prescriptive, neat and linear fashion is not unique to D&T teachers in Singapore (Mioduser and Dagan, 2007; Newton, 2005). Morley (2002) found that:

> It is perhaps natural that the majority of teachers, used to the 'cosy certainty' of technical procedures leading to predictable outcomes, sought to systematise ways of approaching problems to make 'tangible' inherently abstract processes for the benefit of both themselves and their pupils. (p.13)

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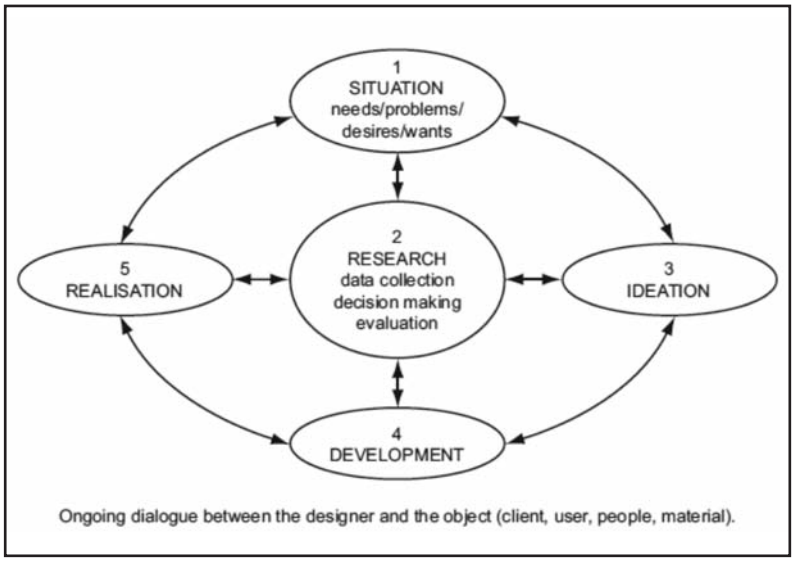

Figure 1. The design model (MOE, 2009)

This arises from the assumption that the act of designing is too complex and is beyond the ability of teenagers. They therefore have to be guided in a lock-step fashion.

There is another view of design, however, that argues that all individuals are innately capable of designing (Baynes, 2006; Stables, 2008). The first author's experiences of supporting D&T teaching in schools suggest that when students are allowed to carry out the process of design in a more flexible manner, they often do not enact a linear and model-driven approach. In this view, then, each student has a unique and creative way of resolving a design problem. Morley (2002) proposed that we first have to "understand the processes of designing so that they may be articulated through teaching" (p.14).

The view advocated by Morley (2002) underpins our investigation of how Singaporean students enact particular design processes in the local school contexts. We accordingly examine how teachers might need to consider teaching D&T students in more iterative ways, rather than following a standard curriculum prescription. Our analysis is student-driven, meaning that we sought to learn about how students go about designing and possibly bring to light certain patterns of thoughts or behaviours exhibited by them. The findings from this study helped us gain insights into the capabilities of students in designing, with the aim of informing Singaporean classroom practice in D&T.

Designing in schools

In most school settings, there will be some sort of model in use to guide the teachers and students in the design process. In this context, it has been found that some designing processes are 'ritualistic' (Denton, 1993; McCormick, Murphy and Davidson, 1994) where teachers tend to follow a very structured approach in designing using a prescribed design model which makes "an abstract process explicit" and leads to "an unnatural perception of order and stages in the process" (Morley, 2002, p.15). The outcomes of students' designs were usually restricted with minimal variation.

Fasciato (2002) compared a few design process models used in school to delineate problems associated with using them in schools. Although the three models were termed as linear, cyclic and iterative in nature, the design stages were flowing from one to another in a linear fashion. It was found that there are "certain elements in common" (Fasciato, 2002, p.31) even though the three design process models appeared to look different. This commonality is reflected in the comment below:

> Having identified a problem, the pupil established the needs to be met by the final solution, carries out research and generates ideas, details a specification, and plans and makes the final design, while evaluating at each stage. (p.31)

This perspective detailed by Fasciato (2002) parallels the prescriptive, linear stage-model that the D&T teachers in Singapore have adapted from the MOE design model (see figure 1). Fasciato views such design models as being restrictive, limiting and constraining the pupil's natural ways in doing design.

Morley (2002) has argued that "designing is a natural, largely subconscious process" (p.14). Reflecting on his one-day in-service course 'Design in The Primary Curriculum', Cross (1992) suggests that "no model will describe the complex process of design" (p.24). Likewise, Chidgey (1994), based on two evaluative case studies conducted with 16 year olds designing projects in Craft Design and Technology (CDT) concluded, that "it is unlikely that 'a' or 'the design process' exists" (p.43). Fasciato (2002) put forward a view that "the nature of design process varies, depending on what is to be designed and who is doing the designing" (p.33). He advocated for allowing "a pupil to design and to chart the process as it occurs, with the teacher negotiating with the pupil" (p.35). This seems to suggest that a more fluid and less restrictive approach could be adopted by the teacher in supporting the students' design process.

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These perspectives signal how the design process should be used more as a guide rather than as concrete steps that each student should adhere strictly to. Schön (1987) declares that a reflective approach is most appropriate to learn design:

> However much students may learn about designing from lectures and readings, there is a substantial component of design competence – indeed, the heart of it – that they cannot learn in this way. A design like practice is learnable but it is not teachable by classroom methods. And when students are helped to learn by design, the interventions most useful to them are more coaching than teaching – as in the reflective practicum. (p.157)

To learn through hands-on practice would mean allowing students to learn in more exploratory and self-reflective ways. The reflective practicum thus calls for the teacher to change his role from one who imparts or transmits knowledge into a coach, supporting the learner in their practices. Lawson (2006) in his final chapter of the book *How Designers Think* also puts forward the case that the "design process can be learned chiefly through practice and is very difficult to teach well" (p.303).

Taken together, the perspectives highlighted above suggest the need for conceptualising students as active participants in the design learning process; in our study, then, we investigated their emergent practices as reflecting a more hands-on and self-driven design experience.

Method

Lawson (2006) commented on the difficulty in conducting empirical work on the design process, as the "design process, by definition, takes place inside our heads" (p. 41). Furthermore, this cognitive process "is not always one which designers themselves would be used to analysing and making explicit" (p. 41). Bearing this challenge in mind, we decided to use the comparative multi-case study (Creswell, 2008) to help us uncover the rich insights into the processes of student designing. We hoped that in comparing two cases of student designing, we would be able to discover similarities and contrasts in students' approaches to designing (Yin, 2009).

In our study, we were cognisant of the difficulty in making the implicit explicit. To meet this challenge, we adapted the protocol analysis which is a common method employed in studies on designing. This is done by observing the subject performing a certain task and 'thinking' aloud at the same time thus capturing the subject's thought and hence the patterns of thought required for the task. Usually this method is employed with experienced designers. There are, however, limitations in terms of capturing the realism as these observations are set up in a controlled timed environment. For our study, we wanted to capture the design thinking process that stretched over a period of eight months. We therefore modified the protocol analysis method in the following ways. Firstly, instead of capturing the 'think alouds' during the design process by audio taping the subject's verbalisations, we referred to and analysed the subject's design journal. All D&T students are required to keep a design journal which could comprise sketches, photographs and research material that help them work towards creating their design. We felt that these journals would be equivalent to the verbal 'think alouds' of the protocol analysis as the journal entries are made throughout the design process. Secondly, when the first author interviewed the subjects, she asked the subjects to draw out their design process and talk about that graphic representation of the process.

Selection of subjects

The main aim of this study was to explore the nature of designing and how this was approached by D&T students at the Secondary Four school level (i.e. 16 year olds). Purposeful sampling (Creswell, 2008) was employed by studying two successful cases of student designing, as recognised locally through the D&T award. The D&T award is an annual event organised by the Design and Technology Educators Society in partnership with MOE and NIE. The D&T Awards is not a competition but a platform on which to give recognition to students and their teachers for their design concepts. These entries were evaluated by a panel comprising designers, design educators and entrepreneurs with vested interests in design. The two cases selected – Case 1, Yvonne, and Case 2, Ron, were winners at the 2010 D&T Awards. The theme for the design project in the two cases was 'Tidiness'. By looking at these works, we were able to gather rich data to set up a focused perspective on exemplary cases of student designing.

Following on from the selection of the two students and their award winning D&T projects, 1) the first author interviewed each student in regards to the thinking behind his/her design; 2) the first author then examined the design journal of their D&T project and finally 3) the first author interviewed each student's teacher on the student's design work. This procedure allowed us to progressively build up the layers of events and occurrences that would reveal the different parameters and factors underpinning the design process.

In this attempt to understand students' conceptions in designing we drew upon the following sources:

1) evaluation of the design journal as a documentation of the student's thinking during the design process;

2) interviews with the student to get an insider view of the actual feelings and thoughts behind the process of designing;
3) students' representation (in a form of a map) of their design process to examine their approach towards designing (at the end of the interview); and
4) interviews with the teacher supervising the student's design process to find out how the teacher guided the student.

The first author employed semi-structured interviews on the design process and the discussion on the student's design journal. Each interview lasted about one to two hours and was held with each participant separately. The interviews were conducted from 13th May 2010 to 6th August 2010 with the students followed by the teachers. All the interviews were audio recorded.

Data analysis

The data collected were organised in a case based manner as findings. For each case, the design journals of the selected students were concurrently examined and coding (based on the design stages in the design model) was done to determine the design process carried out by each student. The codes were matched with the student's design journal to triangulate and consolidate the sets of raw data into individual case findings. These findings were compared and analysed to depict a view of the way a particular group of students went about their design. To achieve this, the analysis first looked at understanding student designing by examination of the design process in relation to their responses in the interviews. Similarities and differences were then highlighted to represent the approaches in designing by the two students.

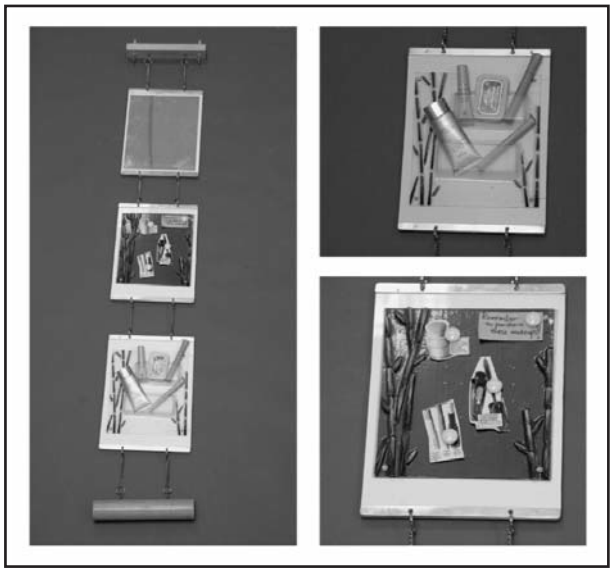

Figure 2. Yvonne's design artefact

Findings

'The Exhibit': Yvonne

Yvonne's design (see figure 2), 'The Exhibit', was a makeup kit holder built into three panels forming a partition that is hung from the ceiling. A mix of materials was used to construct this artefact. Three panels were connected together by chains with two ends linked to hollow wooden poles. The panels were made from plastics with aluminium frames. Each panel had embossed

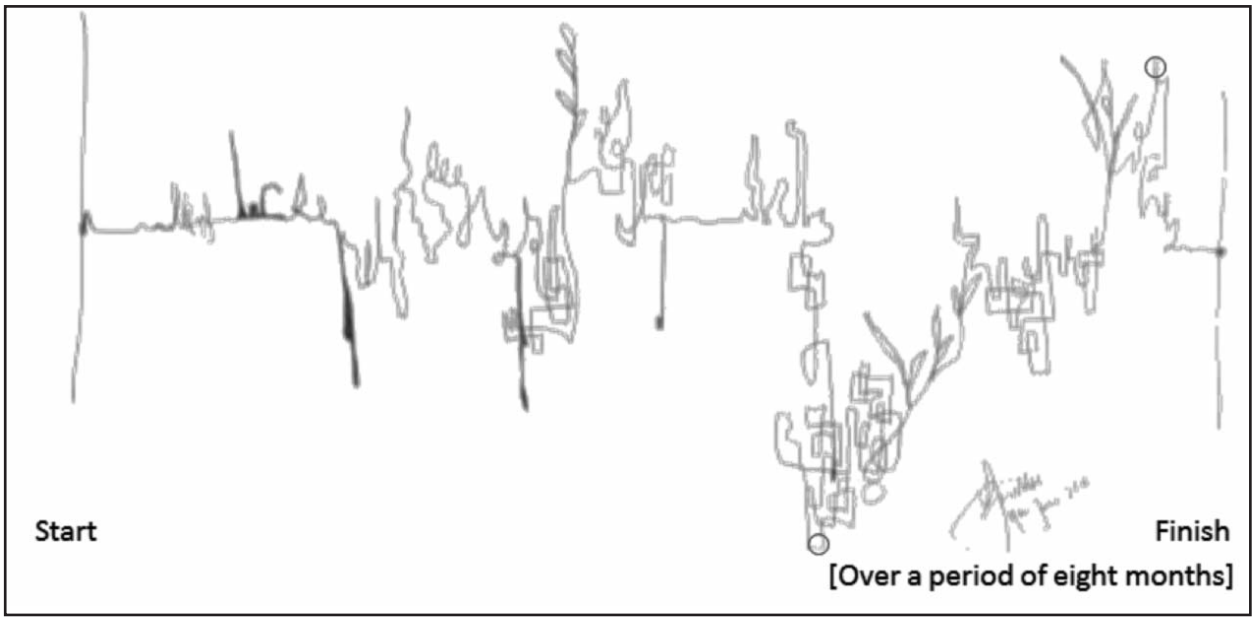

Figure 3. Yvonne's graphical representation of her design process

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bamboo patterns on it and vacuum-formed compartments for storing different cosmetics items. The other side of the panel displayed three paintings drawn by Yvonne depicting three seasons of the year. Her original intention was to paint the four seasons but this was constrained by the design of the three panels.

We managed to piece together Yvonne's design process by analysing her graphic representation, together with her journal, which was a rich collection of mind maps, pictures, photos, drawings and annotations collected during the designing process. Yvonne's graphic representation of her design process is shown in figure 3. She used the 'roller coaster' metaphor to represent her feelings and emotions; the illustration here reflects her stress levels due to coping with many commitments, particularly her coursework in other subjects.

Yvonne shared that she was originally quite lost, not knowing what to do initially. This is represented by the flatline at the start of figure 3. The flatline represented a slow start that caused her a lot of stress as she constantly tried to think up new ideas. Given the theme 'Tidiness', Yvonne started her design similar to other students in the class with a mind map, and a problem situation with some photographs to illustrate her research into possible problem areas like home and school. She narrowed her focus to the home environment.

It was not long before she identified her problem area to work on – the huge mess of makeup items on her dressing table. The design process began to look more positive once she decided on the design problem to be solved. She created an image board on target users, makeup items and bedrooms, and research on existing products. Then she went on to interview target users to understand their needs relating to usage and storage of the makeup items. Research on the sizes of the makeup items was also done. Various sets of research information (interviews and photo analysis) were used to help formulate her design brief and specifications.

Yvonne reflected that she experienced lots of ups and downs throughout the entire process. At the beginning, she was happy when her initial idea emerged, but things spiralled down as new problems crept in. She was constantly searching for new ideas. For example, when she drew up a list of considerations for her makeup holder, she explored no less than four drastically different designs. The first idea she had was about "cute girls who like cute stuff". She used a Manga character, 'Pucca', as the shape of her design. She "wanted something very simple" which led her to select a square shape for her panel. She experimented with a few sketches of flower shape and various shapes of containers and conducted interviews with her friends to get their feedback on her design. She reflected that she could have asked more thought-provoking questions to get more useful feedback. In her ideation stage, she conducted interviews for her first two ideas (in the form of a 'Pucca' with a base) before doing some development work to arrive at idea three – a box-like container. The interviews surveyed the user's preferences in makeup kits and related needs. While she explored these different shapes, she felt that she was stuck in a rut because conceptually, the ideas were the same – a container-like design. After several discussions regarding possible ideas with her teacher, Mr Tan, the partition idea developed, resulting in a drastic change to Yvonne's initial design. This idea was conceptualised through combination of her interest in painting and Japanese culture. Her design journey began to take off thereafter.

This, however, did not mean that the design process after that was smooth-sailing. During the design development stage, she realised that certain parts of her designs failed to work. This badly affected her as could be seen from the lines drawn to the *lowest point* in figure 3. As with the earlier stages in her design process, Yvonne plunged into reams of research on existing partitions, floral themed products, bamboo, sceneries of Japan, emotions of the comic character 'Pucca' and existing compartments to hold small items. In between the research, she interviewed her friends (who were considered potential users) to solicit opinions on their preferences relating to the choice of themes and compartment types. The data allowed Yvonne to decide on the way to organise the compartments to meet the potential users' needs. A good deal of development into almost every aspect of the panel evolved from this point, with further research conducted whenever needed. Finally a paper mock-up was constructed to test and check the final design. A special addition on the contextual use of the design was inserted into her journal. When she realised her D&T coursework was going to be completed successfully, she felt very happy and the lines (see figure 3) were drawn upwards to a *high point.*

Yvonne was exuberant, bubbling with lots of enthusiasm and excitement when she was describing her design process. Many pages in the design journal reflected self-learning and her indulgence in drawing of inspiration from many sources – textbook, design books, magazines and IKEA catalogues. As evident from the entries in her journal and her description of her design experience, it became apparent that she tended to follow her intuitions rather than a definite or prescribed path or route.

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As Yvonne was very motivated and independent, there was not much explicit intervention by her teacher, Mr Tan, except during the ideation stage when she felt somewhat stuck. When Mr Tan suggested incorporating a 'Zen' design, she was really intrigued by this as she liked Japanese designs, flowers and scenery that reflect 'Zen'. Mr Tan mostly monitored the creation of her design. He noticed her design journal was different from her classmates. Yvonne did many things on her own accord, without using prescribed methods (such as SCAMPER[1]) taught to her in the past. The outcomes produced by Yvonne went beyond Mr Tan's expectations, especially the contextual drawing which had not been covered in class before. Yvonne's design was the only one chosen to be submitted for the D&T award as Mr Tan saw market potential in her design suited for local households with space constraints.

'Kirby': Ron

Ron's design (see figure 4), 'Kirby', was a device designed to coil up used guitar strings for easy and safe disposal. The entire artefact is made out of plastics in the form of a musical note. It has a handle to wind up the string into a cylindrical holder which can be detached for disposal of strings. It can be clamped onto one end of the guitar by adjusting the knob.

Figure 4. Ron's design artefact

When Ron first learnt about the theme 'Tidiness', his immediate thinking was along conventional lines (e.g. storage to tidy things up), yet he wanted to do something different, something that he felt nobody had conceived of previously. After considering a few potential problem situations, he decided to select a problem of replacing old or broken guitar strings. Being a guitar player himself, Ron felt that this problem was worth addressing. After conducting some investigation on disposal of used guitar strings, Ron noticed that they were rusty and sharp at the ends. It was also difficult to keep the strings neatly coiled in the dustbin as the coiled string would open up and scatter onto the floor. This, he felt, could become a hazard which may hurt

Figure 5 shows the graphic representation of Ron's design process. The lines go forward and back as he progressed along the way showing a reciprocating process. Ron was using phrases such as "come back to my first thing" and "come down to my problem" when he shared his thinking around the design process. There were a number of turning points revealing how he revisited the initial design stages to help him refocus on his original intention. These were critical points of his design process where he would go back to re-examine, re-check and re-think what he wanted before he moved on to the next stage.

With just 46 pages of design sheets, Ron's entire design looked messy at the outset but this was contextualised by elements of deep thinking that was meaningfully expressed. His design sheets were mainly pencil sketches with traces of erased marks. Some pages had different colours of pen tracings over the pencil markings and there were lots of highlights, pictures, arrow heads and other symbols used for communicative purpose.

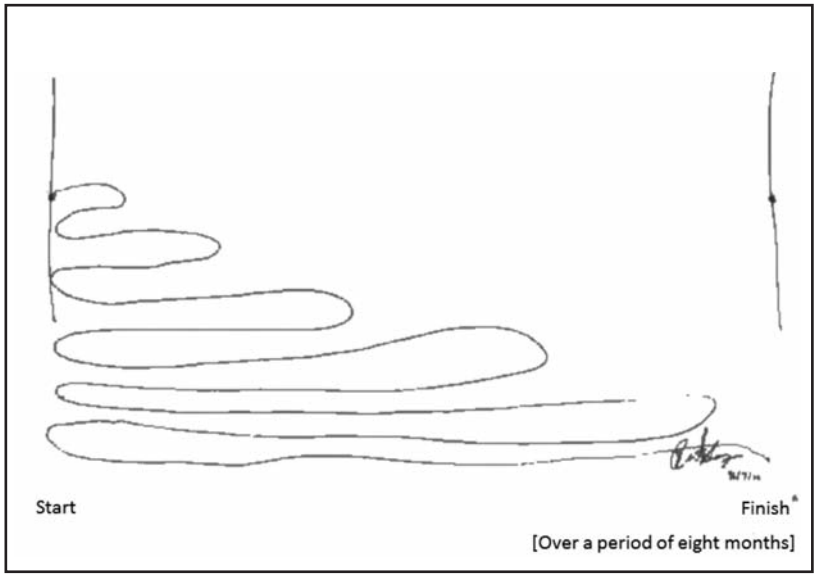

Figure 5. Ron's graphical representation of his design process

[1]*SCAMPER is a design technique used in the Singaporean education system to generate design ideas.*

someone who might accidently step on the string. Ron continued analysing the problem by taking pictures on replacement of the guitar string. He also carried out thorough research on guitars, guitar strings and accessories to better understand the problem areas.

As there were no existing guitar string coilers, products related to coiling things were studied to serve as possible solutions. The fishing reel appeared as the most adaptable solution. The research work Ron conducted was quite extensive and he actually derived a set of design specifications based on the research done. Five sets of design concepts were explored and these included some radical ideas such as the "foot pump" method to reel in the strings and crushed bottles to store the strings. At this stage, everything including existing products was hand drawn with annotations, although pictures could have been used. In conceptualising his ideas, Ron mentioned that he "just looked around and thoughts and things came to mind". He recalled that he kept drawing to see how the strings could be coiled and removed for disposal. For each idea, Ron evaluated it by describing the advantages and disadvantages and possible improvements to be made. Finally, he adopted the fishing reel concept for further development.

Ron arrived at his final design after trying out many prototypes and mock-ups using different materials. Incorporating the form of a musical note, considering ways of holding the string in place, and disposing the strings with ease, were a few of the many considerations and obstacles he had to overcome. Even at the last stage of his design, new problems surfaced while he was testing and evaluating his product. However, time was running out so he had to put a close to his design. He eventually reflected that something smaller and lighter could have been created given more time.

Ron spoke passionately that in designing one should not be held back by previously held assumptions and uncertainties. He spoke little of his teacher's involvement in his design work and firmly stated that he owned about 85% to 90% of the design. He mentioned the need to be open to advice and good time management as important factors in designing.

Ron's teacher, Mr Goh, submitted Ron's design for the award as he felt that the aesthetics part was rather outstanding. In his opinion, Ron was very clear about what he wanted to do from the start and it was an authentic problem he was dealing with. "His ideas were overflowing" and it was "easy for him" noted Mr Goh. Mr Goh's vivid description of Ron's design process depicted a case of a teacher who had closely monitored his student's work. He noticed that Ron had difficulty in drawing and advised him to make prototypes to test and experiment with his ideas. He observed that Ron spent most of his time at the development stage, making attempts to resolve the functionality of the design through multiple trials and errors. The design taking the form of a musical note surprised Mr Goh as it was different from the hairclip form chosen initially. Although both could clamp on to the guitar, he felt that the musical note was a more meaningful form.

Mr Goh found Ron's process messy although he felt that there was evidence of deliberative thinking behind his design. While Mr Goh believed that there was a certain structure that students should follow when attempting their design, he also allowed them to explore and not wait for him to provide the answers. Mr Goh shared that this approach meant slow progress at the beginning, yet this strategy of "wasting of time to save time" turned out to benefit students such as Ron in the long run. Taken together, the views expressed by Ron and Mr Goh illustrate the natural evolution of the design process that is experimental and self-discovery.

Discussion: Understanding student designing in Singapore

In this section, we start by revisiting the approaches Yvonne and Ron enacted as they went about conceptualising their D&T project. Then we examine their processes in relation to the design model by MOE. This led us to conclude that the process in designing may be more fluid and dynamic as reflected in the nexus model. Finally we looked at how the findings reflected divergence from the traditional model used by the Singaporean D&T teachers, which suggests a more facilitative approach is needed to support student designing.

'The Exhibit' by Yvonne redefined the way cosmetics could be organised; 'Kirby' by Ron was chosen for its unique problem – to curl up used guitar strings in a meaningful form of a musical note. The students' descriptions of their design sounded like the "creative leap" mentioned by Cross (2007) which signifies how one's "creative design" process can lead to "novel features for a new design product" (p.65). Looking at the students' design maps in figure 6, there could be many interpretations of their design processes. At one look, it may seem to show their design process is the same, fluctuating at different degree and scale. The interviews however revealed that each student had a different approach to designing.

Ron seemed to be clearer right from the start and his process involved reflecting and revisiting his very first

concepts. To him, designing seemed like a natural process and each version worked to improve on what he had conceived previously. Yvonne's map, which strung up and down, depicts complexities and uncertainties in between phases. Simultaneously, these two representations share many points in common. Both illustrate that the process of designing was not trouble-free. There were many "down" or discouraging moments, and the concept of re-iteration was evident through their drawings of loops.

Although the maps could not represent the student's design process entirely, they demonstrate how the process of designing is unique. This corroborates with the views held by many designers, researchers and educators that designing is a unique personal act (Cross, 2007; Lawson, 2006; Schön, 1990). In this view, there is no way to define or dictate how one should go about designing.

Looking at the students' designing processes, we suggest that an appropriate representation of the design process (in comparison with the two-dimensional, flat model of figure 1) may consist of the various design stages in a nexus (see figure 7) interacting with one another without any designated sequence or order. This means that a student may begin his design process by examining existing solutions then move on to redefine the problem situations, explore some initial ideas through simple models and testing before conducting research to develop the idea further. Therefore, throughout the entire process, the student may transit randomly from one design stage to another as the design evolves.

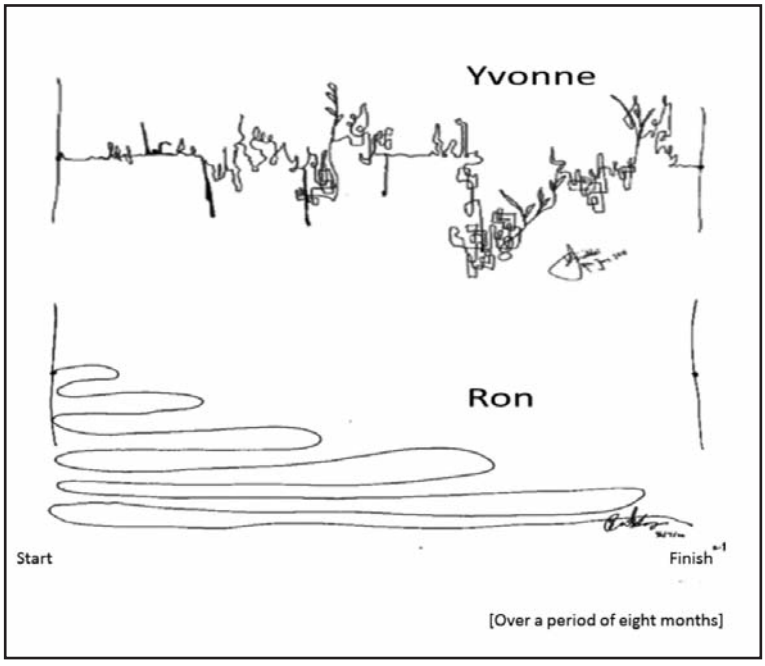

Figure 6. Design maps from Yvonne and Ron

While many D&T teachers in Singapore commonly used the design stages in the design model suggested by MOE (figure 1) as a structure to guide the students in designing, both teachers from the two cases here did otherwise. They did not expect their students to follow a fixed path. They allowed their students to explore on their own, via trial and error to figure things out. Such autonomy and responsibility given to the students supported their design processes as they engaged with many uncertainties and difficulties. This non-linear learning trajectory, supported by the teachers, may explain why Yvonne and Ron were not able to describe any particular approach they were using to design.

Finally, we suggest that teacher intervention was of significance to each student's design. It was found that the critical moments of the design for the students occurred during the dialogue sessions held with their teacher. For example, Mr Tan triggered Yvonne's idea to convert the makeup kit holder into a partition for the room. Yvonne further conceptualised the idea and developed it into a ceiling held partition and makeup kit holder. The teachers here acted similarly to a coach in a reflective practicum (Schön, 1987); working alongside the students, then, the teachers facilitated the students' design processes in a hands-on and supportive manner.

Our study suggests that students who are not trained designers per se do possess innate capabilities to engage in designing. Their approaches to design varied, reflecting diverse interventions, decisions and judgments made at different moments. They engaged with specific design problems, whilst simultaneously constructing new knowledge, skills, and values. Their teachers provided meaningful guidance during the emergence of their unique learning trajectories.

Conclusion

Thinking, drawing and creating in concrete and visual modes were the multiple aspects of designing in action observed in the two Singaporean students highlighted in this paper. In the course of designing, each student seemed to have developed some designerly ways of knowing as identified by Cross (2007). These developments in the students happened naturally as they engaged in their design work. They engaged in multiple modes of interaction with different media, material and people (e.g. friends and teachers).

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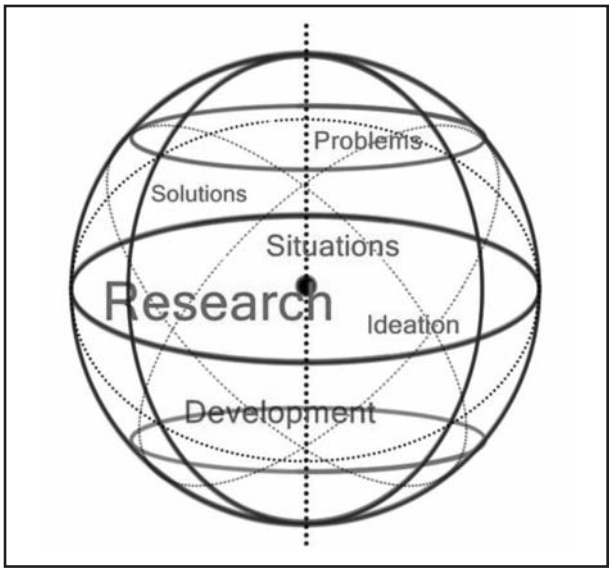

Figure 7. Nexus of design stages

Our use of the case study method was intended to gain a deeper understanding of the intricacies in designing (Creswell, 2008; Yin, 2009). Indeed case studies involve "an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when boundaries between the phenomenon and context are not clearly evident" (Yin, 2003, p.13). This approach was selected in our study of the Singaporean D&T context as it is able to represent the complexity in the design process.

Our findings therefore suggest that Singaporean students should be allowed to practice design in hands-on ways and develop their own particular understanding of their environments and contexts. These findings act as signals for Singaporean D&T teachers to appreciate the complexities and uncertainties inherent to student designing; arguably, there is no one perfect model or pathway that works best for each student.

Within the context of teaching D&T in Singapore, appropriate teacher intervention reflecting the fine art of balancing freedom and control is crucial to facilitate the emergence of students' designs, as noted by Lawson (2006):

> Design education, then, is a delicate balance between directing the student to acquire this knowledge and experience, and yet not mechanising his or her thought processes to the point of preventing the emergence of original ideas (p.157).

This pedagogical stance reflecting "balance" is suggested here as appropriate for D&T teachers in Singapore where they can exercise flexible professional discretion, to create opportunities for students to productively learn from experimenting and even failure.

While such a stance challenges the dominant pedagogical practices currently being enacted in Singaporean D&T education, it is actually aligned with the recent Singaporean curricular policy, "Teach Less, Learn More" (TLLM). Since the introduction of TLLM into the Singapore education system in 2004, MOE has been challenging teachers to explore pedagogies that would "engage our learners and prepare them for life, rather than teaching more, for tests and examinations" (MOE, 2004, p.1). Singaporean D&T teachers, as they come to engage with this view, should therefore perform the role of a facilitative coach who can support and advise students in a balanced manner rather than simply "teaching more" in linear ways predicated with achieving set outcomes. The D&T curriculum, we argue, should accordingly seek to provide more space and time for students to engage in "deep" and reflective thinking as well as hands-on acts of designing in ways reflecting active exploration.

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