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LOH, Wei Leong Leon
Kyushu University

KWEK, Hwee Mui Grace
Dunman Secondary School

LEE, Wei Leong
Dunman Secondary School

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Re-clarifying Design Problems through Questions for Secondary School Children

An Example Based on Design Problem Identification in Singapore Pre-Tertiary Design Education

Wei Leong, Leon LOH, Kyushu University, Fukuoka, Japan, leon@design.kyushu-u.ac.jp

Hwee Mui, Grace KWEK, Dunman Secondary School, Singapore, kwek_hwee_mui@moe.edu.sg

Wei Leong, LEE, Dunman Secondary School, Singapore, lee_wei_leong_a@moe.edu.sg

Abstract

It is believed that secondary school students often define design problems in the design coursework superficially due to various reasons such as lack of exposure, inexperience and the lack of research skills. Questioning techniques have long been associated with the development of critical thinking. Based on this context and assumption, the current study aimed to explore the use of questioning techniques to enable pre-tertiary students to improve their understanding of design problems by using questions to critique their thinking and decision-making processes and in turn, generate more effective design solutions. A qualitative approach is adopted in this study to identify the trajectories of students during design problem identification and clarification process. Using student design journals as a form of record for action and thoughts, they are analysed and supplemented by hearing survey with the teacher-in-charge. From the study, the following points can be concluded: 1) questions can be a useful tool to facilitate a better understanding of the design problem. 2) The process of identification and clarification of design problem is important in the development of critical thinking skills and social-emotional skills of the students. 3) It is important that students are given time and opportunity to find out the problems by themselves. 4) Teachers can be important role models as students may pick up questioning techniques from teacher-student discussions. 5) Departmental reviews and built-in professional development time for weekly reviews on teaching and learning strategies are necessary for the continual improvement D&T education.

Keywords: Design Education; Questioning Techniques; Design and Technology; Critical Thinking

The process of design, on one hand may be understood as a process of rational problem solving (Simon, 1973; Coyne, Rosenman, Radford, Balachandran & Gero, 1990; Liikkanen & Perttula, 2009) and on the other, a process of reflective practice (Schön, 1983, 1987). Design and Technology (D&T), studied as a general education subject in Singapore secondary schools, engaged students with the full range of design activities that span from identifying design problems to the production of solutions in the form of working prototypes. One of the challenges for students towards proposing an effective solution was to clearly understand the design problem before moving into ideation and development of the solutions.

A common technique used to clarify design problems include mind mapping,

conducting field research and interviewing potential stakeholders. General feedback from teachers is that students are looking for the wrong type of information that is not related to the design problem. Also, due to the lack of research skills, students are passive and often dependent on teachers to provide instructions in clarifying design problems. In some cases, in the name of students' inexperience, teachers resort to telling students what the design problems should be instead of allowing students to explore and understand the problem by themselves.

Questioning techniques have long been associated with the development of critical thinking skills. Using Bloom's Taxonomy as a basis, asking higher order questions will require higher order thinking in the form of analysis, synthesis and evaluation. In addition, the skilful use of convergent and divergent questions may facilitate decision making, expansion, exploration and creativity (Elliot, Kratochwill, Cook & Travers, 2000).

It is in this context and assumption that the current study aimed to explore the use of questioning techniques to enable pre-tertiary students in improving their understanding of the design problems by using questions to critique their thinking and decision-making processes and in turn, generate more effective design solution.

Design Problems in the Design & Technology Coursework

It is widely agreeable that nature of design problems are complex, ill-structured with ambiguous goals, without a determined solution path and required the integration of multiple knowledge domains (Reitman, 1965; Simon, 1973; Jonasson, 2000). According to Goel and Pirolli (1989), problems involved in design contain many degrees of freedom, required substantial information collection, problem structuring and negotiation. Much of the information required comes from external sources or prior experience of the designer (Goel & Pirolli, 1989). In addition to the understanding of design problems, a design problem may evolve throughout the design process thus making it hard to identify (Dorst & Cross, 2001; Dorst, 2006). In the design course work, students usually engaged in design problems with little 'design experience'. Although students are trained in problem solving skills in other subjects, most of the commonly encountered problems are well-structured. In handling design problems, students required a different set of problem solving skills to explore into the ill-defined and ambiguous design situations and eventually proposed the most effective and plausible design solution within their own defined constraints.

Questions and Critical Thinking

Critical thinking and the Process of Design

Critical thinking is thinking about one's thinking process; it occurs when a person evaluates reasoning used in coming to a conclusion (Moore & Parker, 2015). According to Butterworth and Thwaites (2013), critical thinking is about making informed evaluative judgements about claims and arguments. As a process, critical thinking may involve three main activities, namely, analysis, evaluation and further argument (Butterworth & Thwaites, 2013). As an ability, critical thinking involves the

capacity to assess and apply evidence to support or evaluate an argument (Watson & Glaser, 2008). In addition, critical thinking can be considered as a rigorous process of inquiring, learning and acquiring knowledge for the critical analysis and evaluation of evidence to justify one's belief (Ikuenobe, 2001). As a critical thinker, several skills are believed to be necessary, such as, interpretation, analysis, evaluation, inference, ability to clarify, decision-making and problem solving.

In the process of designing, critical thinking is very much involved right from the process of identifying and clarifying design problems to the conceptualisation of a suitable solution to the production of the prototype. Whether design is treated as a rational problem solving process or a reflective practice requires the designer to interpret the information related to the design problem so as to propose and evaluate all possible and effective solutions.

Questioning in Thinking Process

According to Chin and Langford (2004), questions can to some extent influence the level of thinking operations that students engage in. Questions may be classified into various categories as such:

- Lower and higher order questions according to different levels of thinking (Bloom, 1956)
- Open and closed questions (Blosser, 1995)
- Productive questions (Elstgeest, 1985)
- Operational questions (Alfke, 1974)

In associating questions with critical thinking, it is believed that questions that require higher order of thinking, such as a) inference from patterns, trends or underlying relationships in data, b) predict outcomes and c) evaluate and use criteria based on given information to make judgement, are pitched at critical thinking level (Chin & Langford, 2004). While questions that involve, a) formulating alternative hypothesis from same observations, b) planning and designing experiments for investigation using tests and c) proposing and generating solution to a problem, invoke creative thinking skills (Chin & Langford, 2004).

The relationship between questioning and thinking can be understood according to Ikuenobe's (2001) analysis on how the process of questioning, for the purpose of eliciting information and justifying one's belief, is necessary for critical thinking. To think critically involves the ability to question and evaluate beliefs, so as to justify and approximate the 'truth' (Ikuenobe, 2001). It is through the process of critically evaluating and questioning a number of evidence that one would then move on to make the judgement that there is adequate evidence to consider it reasonable (Ikuenobe, 2001). Similarly, Siegel (1988) argued that critical thinking involves the acceptance of a belief, based on reasons, after a rigorous process of questioning.

Questioning creates understanding

Ikuenobe (2001) explained that the process of questioning is very much a sequence of

open-ended question and answer, where in this open-ended process, one question may lead to another. It is through this process that issues can continuously be opened-up about the reasonableness of a belief and requires the providence of better evidence and counter evidence. This attitude of critically engaging in inquiry through the process of questioning can be learned if one is taught to appreciate the logic, functions and significance of questioning with respect to knowledge acquisition. Hintikka (1984) argued that questioning offers a useful model for different types of knowledge seeking. These types of knowledge-seeking may include learning, inquiry, eliciting information, reasoning, evaluating evidence and determining reasonableness of a belief (Ikuenobe, 2001).

It appeared that questioning already has a strong research base across disciplines (Duke & Pearson, 2002; Sternberg, 1998). Questioning as a form of thinking, according to Wilson and Smetana (2011) can be a framework for comprehension of expository text and content across content areas. In the process of learning, through questions, a person may make use of questions to independently monitor and regulate his/her thinking. Questioning in turn guide the use metacognitive actions and the answers to the questions may inform the person of the metacognitive task necessary for learning.

Research Methods

Scope of Study

The current study looks into a typical secondary two D&T coursework in a Singapore secondary school. As D&T is only an elective subject at the secondary three and four level, the D&T programme at secondary two level may provide a better reflection on the types of design activities that most of the secondary school students would have gone through in their secondary school education. As the current study aimed to focus on the design problem clarification aspect in the design process, the process of design problem identification and clarification of design problems will be identified and analysed.

Participants

The participants in this study came from a class of 41 secondary two students in an autonomous secondary school in Singapore. The D&T programme in this autonomous secondary school is widely recognised by the local D&T fraternity to be well established among the secondary schools in Singapore. At secondary two level, the students are generally around the age of 14 and will have prior D&T knowledge based on the initial study of D&T in secondary one. Throughout the design coursework, students were grouped to work in pairs although most of the processes were to be done as an individual work. During a discussion with the teacher teaching the class for D&T, it was understood that not all of the work done by students present a good representation of D&T learning in the class. Some of the works done by students were lacking in documentation on the processes which provided a challenge for accurate analysis. Some students were not able to produce good quality work due to heavy commitments in other school activities. Out of the 41 students, work done by nine students were selected as representatives of the typical D&T work done in the class. The grouping were as follow: Group 1, Group 2, Group 3, Group 4 and Group 5. It should be noted that Group 5 consisted of only one student. The grouping of students is as shown in Table 1.

Table 1: Grouping of Students in Each Group.

Group	Student
Group 1	S1A
	S1B
Group 2	S2A
	S2B
Group 3	S3A
	S3B
Group 4	S4A
	S4B
Group 5	S5A

Procedures

During the design coursework, students record their course of action and thoughts into the design journal. Besides, students often have individual consultation sessions with the teacher-in-charge so as to allow the teacher to understand the challenges that the students are facing and also to guide the students.

As such, the current study is based on a qualitative approach that aims to analyse and understand the design problem identification and clarification trajectories that the students have taken during the design coursework. The main piece of data that is analysed in this study is based on the design journals done by the students. From the journals, the analysis mainly focuses on the process of design problem identification, and particular attention is placed to review how the usage of questions may enable students to clarify their understanding of the design problems.

Although it is understood that the design journal may not be able to provide a 100% record of the design problem identification process; verbal feedback and discussions with the teacher-in-charge provide essential supplementation to the information that may not be recorded in the journals. As such, interviews with the teacher-in-charge are conducted throughout the data analysis process.

Research Findings

Overall View of Coursework Tasks

The secondary two D&T design coursework spread over 14 weeks with a 2-hour lesson each week. The students engage the design coursework in pairs but due to the odd number of students in the class, one of the students worked as an individual. The main stages in the design coursework include:

1. Identification of Design Problems
2. Idea Conceptualization
3. Design Development
4. Prototyping
5. Evaluation

Although students are grouped to work in pairs, they are required to work on stages 1, 2 and 5 individually. They submit their work related to the three mentioned stages as individual work.

The Flow in Identification of Design Problems

In the stage of design problem identification, given a theme, students start off with brainstorming to scan and identify possible design problems. There is no restriction on the type of strategies that students can use during the brainstorming process. The underlying rationale is that there is no single approach towards the identification of design problems. As such, students can make use of any strategies they know during the brainstorming session.

From the brainstorming process, students then move on to select a few prospective design problems for further clarifications. It is after this clarification that the members of each group come together to decide and select a design problem to engage further as a group. Just before moving into the Idea Conceptualization stage, students work as a pair to conduct further research to facilitate idea conceptualisation. This flow of the process is presented in Figure 1.

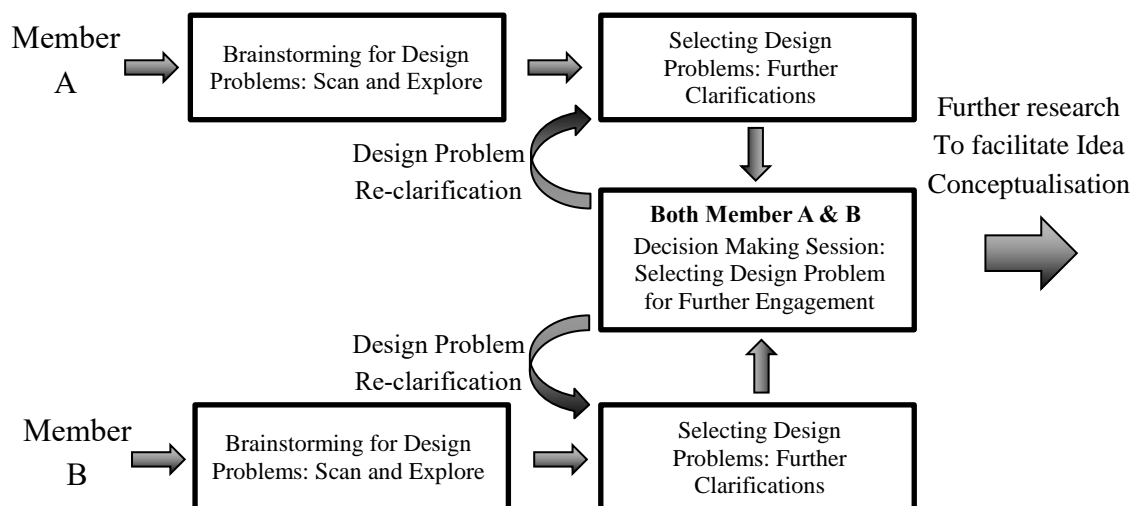


Figure 1: The Flow during the Identification of Design Problem.

At this point, some details should be mentioned during the *further clarification* stage

for selected design problems. In this process, a critical thinking template is created by the D&T department to help students critically assess their perceptions and understanding of the chosen design problems. The critical thinking template is created due to the observations and experience from D&T teachers in supervising design coursework in the previous years. From those observations, the D&T teachers observed that in general, students' understanding of design problems are superficial. As students are low on exposure and life experience, perspective and understanding of the design problems are mainly based on their prior knowledge or experience. In addition, there is also no habit of critical inquiry and research to find out and understand more about design problems.

Based on the concept of Paul and Elder (1996, 2002) on strategies for critical thinking, the critical thinking template is a template that requires students to clarify three main questions,

- 1) Is the problem or needs clear?
- 2) Is my thinking accurate?
- 3) Is my thinking only from my point of perspective?

The critical thinking template adopted some of the universal standards, as suggested by Paul and Elder (1996, 2002), that can be applied to check the quality of reasoning about a problem, issue or situation. The universal standards used in the template are related to, *Clarity*, *Accuracy* and *Breadth*. It must be noted that the first use of the template was in 2012 and the original template contained more standards than the current version. However, according to the teacher-in-charge, students are not able to handle and work on so many universal standards at one go. As such, only three of the standards that are deemed to be most achievable and useful for students to critically assess their thinking in the current context are used.

Within each of the main questions in the template, students are required to come out with sub-questions to guide themselves during the clarification process. In the end, students are required to redefine the problem or needs identified. Figure 2 shows a sample of the critical thinking template used in the design coursework.

Moving on to the next part of the finding, the design problem identification and clarification trajectories of the students is presented. The main focus is to highlight the use of questions to clarify and understand selected design problems and lead to the decision-making process in selecting the design problem for further engagement. The presentation will be divided into two main parts, 1) Brainstorming session and 2) Selecting and further clarification of design problems.

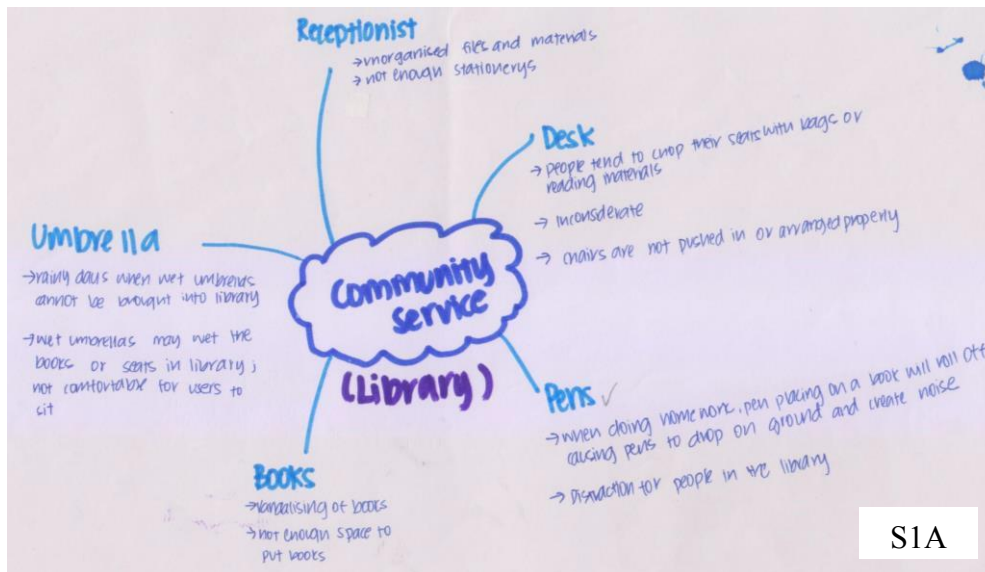
Name:	Class:	Name:	Class:
Problem/Needs identified		Redefine problem or needs identified	
Is the problem or needs clear?			
<i>Sub-questions</i>	<i>Answers</i>		
Is my thinking accurate?			
<i>Sub-questions</i>	<i>Answers</i>		
Is my thinking only from my point of perspective?			
<i>Sub-questions</i>	<i>Answers</i>		

Figure 2: Critical thinking template used during the design coursework.

Brainstorming Session

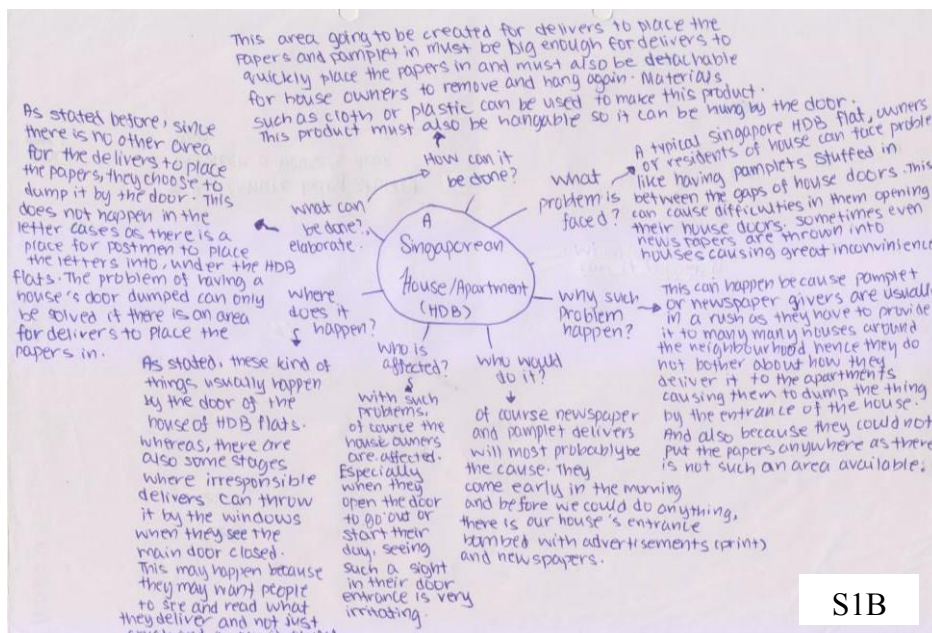
In the brainstorming session, students started off to explore possible design problems. It is observed that students employ two to three main approaches in general. These methods are mind mapping, problem-solution analysis and a hybrid of mind mapping cum problem-solution analysis.

In the use of mindmaps, it is observed that the quality of exploration differed among students. For example, referring to Figure 3 and 4, in the exploration done by student S1A, the areas of interest are listed followed by short notes. Whereas for student S1B, she made use of questions that start with *How*, *What*, *Why*, *Who* and *Where*, to guide the exploration process.



S1A

Figure 3: Exploring possible design problems using mindmaps by student S1A.



S1B

Figure 4: Exploring possible design problems using mindmaps by student S1B.

It can be observed from the mindmap that student S1B jotted down deeper thoughts into the journal as compared to her partner where the exploration of design problems are more superficial. At this point, it is necessary to highlight that, through the questions, student S1B tried to provide the rationale behind the various aspect of the design problem which may bring about better understanding of the design problem.

For students who approach the brainstorming session using problem-solutions, students mainly identified possible problems and tried to suggest certain solutions to the problems. Some examples of such approach are presented from Figure 5 to 8. A common observation found in these three examples is that the design problems, which is the main aim for exploration, are quite briefly analysed by the students. All students tried to state the main perceived problems, but all failed to provide at least some basic

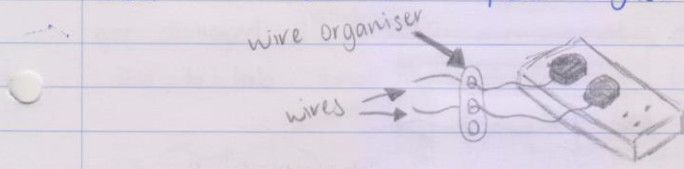
underlying reasons to justify the problems that they perceived are in fact problems.

8 Problems & Situations S3A

- 1) A box that is specially made for pamphlets to be placed at the door/ outside the house instead of just placing it at the door handle. When there is too many pamphlets at the door, it will look very messy and untidy, also this can cause more litters to be found around the housing blocks.
- 2) The rim of the pails at home curved outwards which cause water to spill easily when there's a large volume of water. Therefore, if the rim of the pail curved inwards instead, even with the same volume of water, it will not spill easily.

Figure 5: Exploring possible design problems through problem-solution by student S3A.

1 Wire organiser
Wires get tangled up easily and are hard to untangle. Some wires also look similar. Hence, introducing a wire organiser will make wires neater and prevent tangles.



2 Security cameras in lifts
All lifts have rules, with the most common one, the no smoking rule. However, not many people followed the rules despite having the punishment stated. Hence, security cameras should be installed to keep track of the happenings in the lift. The wrongdoers can then be dealt with severely.




Figure 6: Exploring possible design problems through problem-solution by student S3B.

No.	Problem	Improvement
1	Wet weather causing walkways to be slippery	Build railings to hold to prevent slipping and falling. Build a more efficient water damage system to drain water faster to prevent water from collecting. Build anti-slip floor to prevent slipping.
2	Bus floor becomes wet due to the umbrellas on a rainy day	Build an umbrella holder in a bus or build a stand holding plastic bags to put the umbrellas in.
3	Bus stops have a lack of seats due to a long bus waits when travelling a long distance.	Increase the number of seats in the bus and increase the number of buses services to shorten travel time as there are more routes.

Figure 7: Exploring possible design problems through problem-solution by student S5A.

① People who are weaker may have problems opening the door as they may not have enough strength to use the door knob.

② Some people may not have enough power to open a bottle cap.

③ Erasers can get very dirty when

Create a product that would help these people open the door with ease. (For example, a cover for a door knob.)

Create a product that would help these people open the bottle cap with ease. (For example, a cover for bottle caps.)

Figure 8: Exploring possible design problems through problem-solution by student S4A.

Community Service

- Kitchen**
 - PF: When people have items that they need to reach from a high shelf, they are forced to climb chairs or tables to reach them. This is dangerous because they may fall and injure themselves.
 - I: Design something that has a long handle so that it is easier to reach items that are on a high surface without having to climb other surfaces first.
 - PF: Cans of cold beverages (when placed on wood tables) may cause there to be puddles of water left behind on the tables.
 - I: Design a can holder that prevents cans from leaving behind puddles of water. The can holder must be made of a waterproof material.
- Food Court**
 - PF: In outdoor food courts, birds can often be seen eating leftover grains of rice on the tables. The amount of people that are able to find places to sit are also lesser because of the bird waste that can often be found on the tables.
 - I: Hang compact discs from the ceilings all around the food court. The light that will shine into the birds' eyes will scare them away from the food court.
 - PF: In outdoor food courts, because of the leftover food, many flies and other pests are drawn to them.
 - I: make use of nets to prevent flies from going near the food court area.
- DLT Workshop and writing surfaces**
 - PF: After every DLT lesson, there are always students who find it hard to collect the eraser dust from the tables for disposal. This gives the school's cleaners an extra task when students can simply complete it themselves.
 - I: Design an eraser dust collector that is portable so that students can move the collected eraser dust from the tables to the bin with ease. They will be able to collect the eraser dust without using direct contact with the hands.
- Old Folks' Home**
 - PF: While elderly are often given assistance when they are in an elderly home, there are some who want to try to be more independent. When they are having meals, they are often try to separate their foods on the plate.
 - I: Design a plate that is divided into a few parts, labelled with the different dishes so they will be able to control their meals easily.
- Bathrooms**
 - PF: Metallic toothbrush racks often end up becoming rusty easily.
 - I: Design a toothbrush rack that is not made of metal so that it will last longer.
- Hawker Centre**
 - PF: Even when ordering the smallest of meals, people also always have to join an extremely long queue.
 - I: Introduce an express queue that allow people who want to order small meals to receive their meals faster.
- Cyclists**
 - PF: Many cyclists often leave their bicycles unattended at home when going out.
 - I: Design a bicycle theft alarm that is small and cannot be easily seen. The indicator can be easily portable and brought by users.
- Libraries**
 - PF: Books are often strewn on tables with a lack of organisation.
 - I: Design more creative bookshelves cum bookshelves to increase organisation.

Figure 9: Exploring possible design problems through problem-solution by student S2A.

It seems that the lack of depth in understanding the main cause of the design problems and providing reasonable justifications to support their claims are common among students. In fact, such similar observations can also be observed for students who tried to brainstorm and explore problems using the hybrid between a mindmap and problem-solution analysis, refer to Figure 9. Such observations may suggest that the depth of understanding of design problems does not hinge on the types of approach but may be related to the ‘way of thinking’, in other words, the habit of the mind to critically assess one’s thought and believe.

Selecting and Further Clarifying Design Problems

As it is expected that students might not be able to critically assess and evaluate their perception and belief about a certain design problem, the critical thinking template was introduced as an intervention to ‘facilitate’ students to look into the ‘matter’ more critically. It appears that the critical thinking template does have some effects on students who have initially explored the design problems very superficially. As the whole, when students re-define and re-write their design problems, improvements in clarity and depth can be observed across all the students. While the level of improvements varied among the students, this study did not go into a more specific analysis to detail the specific level of improvements in each student. An example of the critical thinking template, when done by students, is shown in Figure 10.

The figure shows a student's handwritten work on a critical thinking template. The template is divided into three main sections, each with 'Sub-questions' and 'Answers' columns. The student has filled in these sections with handwritten text and diagrams. The second section also includes a sub-section 'Is my thinking only from my point of perspective?' with its own 'Sub-questions' and 'Answers'.

Page 1

Figure 10: Exploring possible design problems through problem-solution by student S1A.

Though improvements can be observed in general, the critical thinking template seems to have a magnifying effect on students who are already 'good'. For example, for student S1B, who is already able to explore the design problem with quite some detail, the template seems to help the student to elicit more information and inquire more critically into her own reasoning process. At the same time, expanding the breadth of her critical thinking process as she seeks other perspectives through research related to the problem. An example of the critical thinking template and research done by student S1B is shown from Figure 11 to 15.

Figure 14, shows an extremely long redefinition of the design problem or needs. In fact, student S1B wrote about her findings and analysis of the design problem instead of describing the design problem concisely. While students are required to redefine their design problem concisely, nonetheless, this information provided a form of documentation and evidence towards the quality of her findings.

Problem/Needs identified	
<p>The owners or residents of a typical Singapore HDB flat face one common problem of pamphlets being stuffed in between the gaps of house doors. this can cause difficulties in them opening the house doors or giving an untidy and messy look. Sometimes even newspapers are thrown through the gaps of doors into the house thus causing inconvenience.</p>	
Is the problem or needs clear?	
Sub-questions	Answers
<ul style="list-style-type: none"> - why people throw inside the house? - why cannot open the door or why does it appear messy? - why do they receive such pamphlets or newspapers? - what do the residents usually do? - who is in the wrong? 	<ul style="list-style-type: none"> ① We have never seen a pamphlet giver walking terribly slow, have we? They usually are giving an appearance as if in a rush to catch a train. This is why they usually throw the pamphlets inside our houses as they may find it as a faster and easier way and also that we would definitely see and read it. ② As the pamphlets are usually thrown inside the house by the door step or door itself, after a while if the pamphlets are not cleared, when opening the door, they may cause difficulties. ③ Usually advertisements come in print or electronic form. Advertisers find it easier to convey the advertisements through print form as they may find it as a direct message to the public. ④ Residents usually throw away the pamphlets or sometimes read it. (according to a survey done). ⑤ In this problem where many will blame the pamphlet giver, we should also consider ourselves. This problem would only be a big problem if we do not clear the pamphlets soon enough.

Figure 11: The original design problem statement and the aspect of clarity about the problem by S1B.

Is my thinking accurate?	
<p>Sub-questions</p> <ul style="list-style-type: none"> - How do I know? - Are people really affected by this? - What are they really affected by? - Are the pamphlets really stuffed in between gaps? 	<p>Answers</p> <ol style="list-style-type: none"> ① According to a survey conducted by me, I found out that residents of HDB flats find the problem of pamphlets being thrown in their houses irritating as they find it useless. They think that pasting those advertisement by the lift could be fine as they need to stand there for some time while waiting for the lift. But pamphlet givers may not be permitted to do that. ② According to my survey, many adults are affected by this problem as they are usually the age group who run the house. The children and elderly are not really the one who is affected. As pamphlet given usually do not have them as the target audience. ③ When we talk about who is affected, we have to look at both parties, the residents and the pamphlet givers. While the residents find it irritating, the pamphlet givers may find it as the only easy way. So a product to help both of them. ④ The pamphlets are usually stuck between the door gaps. While in some occasions, they are thrown inside the house. Usually the things thrown inside the houses are newspapers.

Figure 12: The aspect of refining accuracy and validity of the problem by S1B.

Is my thinking only from my point of perspective?	
<p>Sub-questions</p> <ul style="list-style-type: none"> - Am I the only one affected? - Who else could be affected? - Who else would agree with me? - Do the pamphlet givers find it easier to do this? 	<p>Answers</p> <ol style="list-style-type: none"> ① While my family members are affected, from the surveys I conducted, I also found out that other residents are also affected. While some of them find it ok when the pamphlets are conveying an important message, some find the whole thing as a trash as residents find it as the wrong way to convey them. ② Because of this, both the residents and the pamphlet givers are affected. Because of the pamphlets thrown in their house, the residents are irritated as they find it as a trashy thing which gives an messy look, thus throwing away the pamphlets. And because of that, the pamphlet givers are also affected as their message is not conveyed. ③ Many may agree with me especially the ones who run a house but the pamphlet givers may disagree. As they think in their own view, we have to look at everyone's opinion to give comfort to all. ④ Of course, pamphlet givers would love to do this. As they are always in a rush, they find it easier to leave the pamphlets in a bigger area than to keep it in an compressed place or bag. To solve this problem, a product which comforts both the givers and receivers to be happy.

Figure 13: The aspect of seeking other perspectives about the problem. Done by S1B.

Redefine problem or needs identified

Residents have a problem of pamphlets being stuffed between the door gaps. This is basically because, there is no holders for the pamphlets. As pamphlet givers are usually very fast trying to distribute the pamphlets to all the houses, they usually find the door gaps a best area to place the pamphlets as they think that residents can definitely see their pamphlets if it is in the door gaps. Whereas, most residents find it irritating as for the first reason it is not nice looking and they do not want the pamphlets at all but we cannot stop pamphlets as it might be useful. In that case, this problem would be solved if there is a pamphlet holder by the door. From one of my evidences, who already have a holder by the door given by the government, I got to know that it would be better if the pamphlet holder is more innovative and attractive design wise. My evidence prefer it to be a single compartment as it would be too complicated to have many compartments. She also does not want it to be too big as it may give an unpleasant look. Looking at both the pamphlet givers and residents, the best solution for this problem would be having an attractive and acceptable holder for the pamphlets by the house door. Sometimes, pamphlet distributors would be giving out small cards such as visiting cards of hotels, restaurants or house agents. Hence they may find difficulties in giving it to residents as the cards are too small to be kept between door gaps and if thrown inside the house, residents may just dispose it either out of irritation or thinking it is trash or sometimes they may not even look at it if the cards flew under furnitures. At times it might be uneasy for them to call out residents personally and give them the cards. But with the help of pamphlet holders, they can just place it in it and the residents could

also look at the information they are trying to tell us. With pamphlet holders, both parties would get benefited as the residents would not get irritated looking at brochures or pamphlets being stuffed in their door gaps and pamphlets givers also do not need to roll or fold their pamphlets just to stuff it between door gaps and it would also be easier and faster for them to distribute the pamphlets as they do not need to waste time folding or rolling the brochures.

Figure 14: Redefining the problem. Done by SIB.

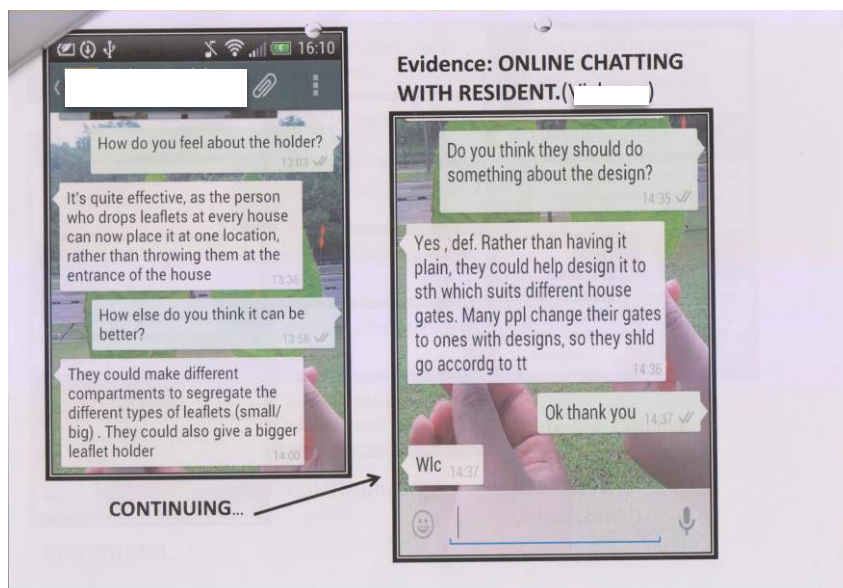


Figure 15. Research to elicit different perspective about the problem. Done by S1B.

For students who had explored the design problem very superficially, the critical thinking template 'force' them to look into the problem in more details. An example may be shown from Figure 16 to 18. This is attributed to the sub-questions that they need to ask themselves and at the same time, find out the 'answers' to their own questions. In addition, teachers also provide comments and guiding questions when checking students' journal. Besides, students are also given the opportunity to comment and feedback on their partner's analysis and understand of the design problem.

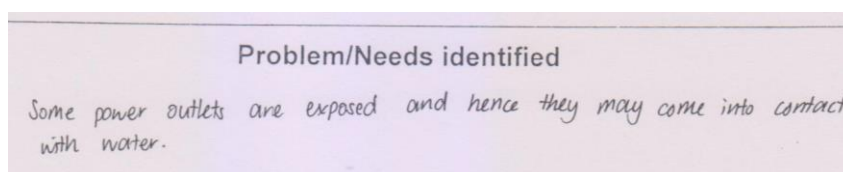


Figure 16. A very superficial design problem exploration. Done by S3B.

Is the problem or needs clear?	
<p>Sub-questions</p> <p>① Why will power outlets be exposed? ② What will happen when power outlets come into contact with water? ③ How do short circuits occur? ④ Where are power outlets usually located at? ⑤ Who will usually use the power outlets? ⑥ Why might power outlets come into contact with water?</p>	<p>Answers</p> <p>① There are no wires that are plugged in to the power outlets ② A short circuit will occur, causing circuit damage and overheating. ③ Short circuits occur when power outlets come into contact with a liquid. <small>The power outlets are usually located</small> ④ At home. ← <small>which part</small> near the floor ⑤ House owners or people who do a lot of technical work. ⑥ The user might have been careless and accidentally spill some water on the power outlets. why? because what happened</p>
Is my thinking accurate?	
<p>Sub-questions</p> <p>How do you know? How often does it happen? where are your evidences? ↳ How to find evidence?</p>	<p>Answers</p> <p>Sometimes, I will read about accidents that are caused by short circuits, on the newspapers. The accidents are usually due to the carelessness of the user. They do not happen often but they are likely to happen when the user is clumsy. The clumsiness of the user can lead to a serious explosion, causing serious injuries and a lot of damage. "I think that power outlets are very dangerous, especially when there are kids around. I remember there was once when my son stuck things in the outlet out of curiosity. It was so dangerous! He could have been electrocuted!" - Mrs Lee "Yes yes, they are dangerous. I just recently spill water onto one and I heard weird sounds coming from it. I thought that it was spilt and did not dare to touch it." - Jake</p>
Is my thinking-only from my point of perspective?	
<p>Sub-questions</p> <p>Did I consider other people's views on this problem? what can I do to get more information?</p> <p>where? - home who? - you didn't specify ↳ house owners technical workers Describe your problem clearer.</p>	<p>Answers</p> <p>Yes. I feel that I should speak to different house owners and gather their opinions about this problem. Who? what are you going to ask? questions: 1) Do you think that power outlets may be dangerous? why? 2) Have you faced any problems regarding power outlets?</p>

Figure 17. Assessing different elements of reasoning though *Clarity*, *Accuracy* and *Breadth*. Done by S3B.

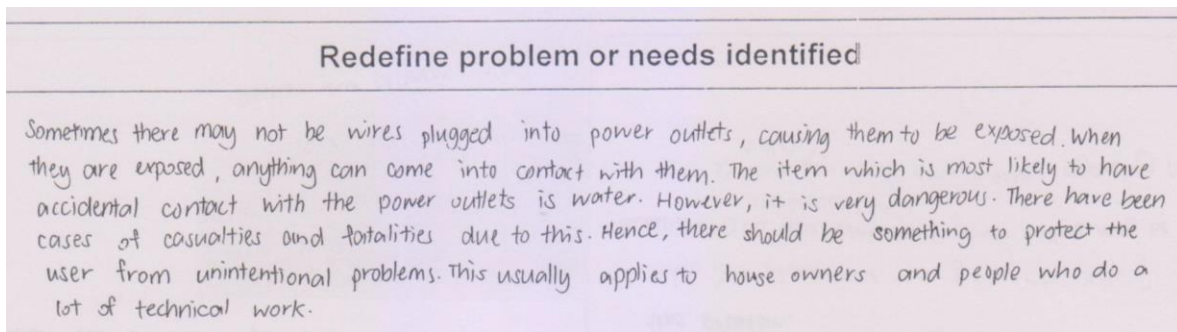


Figure 18. Redefining the problem. Done by S3B.

Through the sub-questions, students, in general, get to explore the different aspects related to their design problems. It is unsure if students have thought about these questions during the brainstorming and exploration process. However, through the initial design problem statements, where most of the design problems are in a way superficially written by most students, it may be assumed that it is during this stage of critical thinking process that students started to think deeper about the design problem. Perhaps this perspective can also be supported by some of the students' reflections where they mentioned that the overall design problem identification process had helped them to consider deeper and gain new insights towards the actual needs of stakeholders. In addition, through critically assessing and justifying their perception and beliefs about a certain problem, students are required to be more observant. Part of the extract of student reflections are shown in Figure 19, 20 and 21.

During the D&T lessons, I have learned many things and values. The first task we were asked to do was listing down problems/situations. Ms [] only told us to do fifteen problems. I didn't think that was a hard task as I thought any problem she would accept. However, when I came up to her and she asked me to think of more problems. I was not sure why I have to do more than some other of my classmates. Hence, Ms [] taught us to practise critical thinking which means to think carefully and this really helped me to list down some GOOD problems in the end. Just completed the 'first stage' of D&T, I was already quite tired of the subject. Therefore, critical thinking really taught me to think deep and consider about the community needs and wants. There was also a time where I was having difficulty

Figure 19. Extract of the reflection by S1A.

Our first theory assignment was to come with 20 problems that surface in the community. There were many problems that were right in front of my eyes. However, I have to be observant enough in order to see these problems. It was very difficult for me to think of 20 problems but sometimes, two pairs of eyes are better than one. I asked my family members and some of my friends if they are able to see the problems in the community. Hence, we have to be very observant. I also had to have the confidence to interview strangers about

Figure 20. Extract of the reflection by S2B.

My partner and I have been working on a problem that the general Singapore public faces in their lifestyle. With research and experience, we have figured out that there are pamphlets being stuffed between door gaps and it is not really pleasant to look at. At times we even wondered if the doors of the HDB (Housing Development Board) blocks in Singapore are actually designed for stuffing pamphlets. Well after confirming the problem, to find out others' opinions on this situation, we went around our neighbourhoods and neighbouring areas to interview people and get some evidence through the form of hand taken pictures. Then only have we realized that this problem was not really minor but had a great impact on the people. We also found out that the Singapore government has done something to help the people. However, it only helps reduce the problem but not solve it. What is the step taken by the government? The residents of Pasir Ris recently received

Figure 21. Extract of the reflection by S1B.

According to the teacher-in-charge, before the use of the critical thinking template, the teacher had gone through a discussion session with the students by giving them some examples of superficial design problems and using questions to guide students in providing more clarity and understanding towards the problems. After the discussion session, students moved on to engage into clarifying their design problems using the critical thinking template. From the sub-questions that students had come up with, it can also be observed that most of the sub-questions are of higher order thinking or open-ended. It is an interesting observation as students have not been specifically trained to ask lower and higher order thinking questions. In a way, students have plenty of opportunities to sharpen their critical thinking skills through higher order thinking questions.

Discussion

Questioning as Tool Towards Design Problem Clarification

When presented with a design problem, the previous experience and prior knowledge about the problem will naturally be activated to provide an immediate understanding, perception and belief about the cause of the problem. In most cases, students often showed a lack of experience and prior knowledge about the design problems that are identified. In order to bridge the gap between students' level of understanding about the problem and the reality, the current study has presented evidence to show that questioning can be an effective scaffold to help the students critically assess their

thinking and evidence on hand about a design problem. Subsequently, it leads to the eliciting of information for new knowledge acquisition for the critical analysis and evaluation of evidence to justify their beliefs about the problem. During this critical analysis and evaluation process, students are required to be more observant during their research, and truly understand the issues and needs of the stakeholders. As such, learning takes place.

While the critical thinking template is created to facilitate the process of critical thinking, this template does not aim to get the students to follow a set of procedures or format in doing things. However, more importantly, by going through the process of critical assessment of thinking and reasoning, it is the internalisation of the attitude and ability in using questions in the critical thinking process that is the underlying aim for the use of the critical thinking template. Internalisation, in a sense, is to become part of the thinking habits in the student as a person. In this case, such attitude and ability may be applied across subject domains and may facilitate the development of the student as a life-long learner which is critical in the 21st century. As a general subject, D&T has an enormous potential in this aspect of critical thinking development.

The Importance of Design Problem Identification Process

If it is justified that the process of questioning facilitates and strengthen the development of critical thinking skills, then it may be assumed that the design problem identification process is as important to any other parts of the design process, such as idea conceptualisation and prototyping in the learning of design in D&T. As questions influence the level of thinking operation, the design problem identification process provides a rich ground for the development of higher order thinking skills due to the open and ill-defined nature of design problems.

As it can be observed in the students' trajectories in identifying and clarifying the design problems, there is no definite answer to the design problems, in other words, no one answer is correct. The answer towards the design problem may evolve as students clarify the design problem is further. As such, the process of critical assessment of thinking and reasoning about the design problem allows students to understand the true nature of the world around them which they may have taken for granted. Additional to developing the cognitive aspect of the students, the process of identifying and clarifying design problems also develop the social-emotional aspect of the student. By developing a better understanding of the problems and needs of people, students may get to have more empathy and heart for people.

Thus, it is imperative that D&T teachers continue to provide opportunities and time for students to critically explore, scrutinise and define their understanding and beliefs about design problems during the D&T coursework. Sometimes, teachers may have the tendency to tell the students what the design problem should be, in the name of helping the students and time saving; such actions may take away their opportunities to learn about our world through design activities.

Teacher as a Role Model

While students are not taught on the theoretical aspect of lower and higher order type of questions, students ability to ask mainly higher order questions when using the critical template suggested that they may have picked up this skill during the discussion session. As mentioned in the findings, the teacher-in-charge provided some examples of superficial design problems and tried to get the students to think about the actual cause of the problem by asking them questions. In a way, the teacher is setting herself as a role model in using questions for critical assessment, reasoning and evaluating the understanding of the design problems. As such, role modelling, a traditional teaching and learning strategy, can be a fundamental strategy in teaching students how to question during the design problem identification and clarifying process.

The Importance of Teacher Professional Development Time

While the professional development of D&T teachers in secondary school is not the focus of this study, but during this study, the authors believe that the current study may be a good example to highlight the fruits of teacher professional development time in the school. In order to keep the design education relevant, the D&T department holds annual year-end review sessions for the D&T programmes and teaching pedagogies. It is during this type of review sessions that the D&T department teachers, based on their teaching encounters and experience, surfaced issues in the design problem identification process and the challenges that students faced. Through discussions and review of relevant theoretical references, the critical thinking template was conceived and implemented. While an implemented teaching and learning (T&L) framework and strategies required constant reviews, the D&T teachers make use of their weekly professional development 'white space' to review the critical thinking template and continue to sharpen the T&L framework and strategies. In other words, design educational programmes, T&L framework and strategies need regular reviews to keep them relevant to the needs of the students. In this sense, professional development time and regular 'white space' for educational reviews will continue to be a vital clog for the development of design education at pre-tertiary level. Perhaps, this may also be true for other subject areas.

Limitations to current study

The findings in the current study are based on the design coursework journals and feedback from the teacher-in-charge. Most of the observations and assumptions in the findings are based on the documentation done by the students in the journal. As such, it is also believed that not everything is measurable or observable based on the journals. Language and writing competencies of students may play a part in the ability to document detail findings and evaluations. In addition, some students may not be able to articulate their thoughts that well during the discussion session with the teacher-in-charge. Thus, the journals may only be able to provide a certain resolution towards the understanding of the students' trajectories towards the identification and clarification of design problems. Besides, the attitude of students also played a part in the quality of the work. Thus, when it is assumed that a superficially identified problem may be due to competencies, in fact, it may be due to the effort of the students.

Another point to note is that journals from previous years are shown to the students for reference. This may also have a certain impact on the quality of work done by students as they are aware of the expectations of the output for their design journals.

Last but not least, during the brainstorming session in exploring possible design problems, the current study allowed students to make use of divergent processes that they are familiar. Perhaps, interventions should be done during the design problem exploration process so that multiple divergent processes may be explored to exploit the effective use of questions to sharpen students' exploration of design problems during the brainstorming session.

Conclusion

In conclusion, the current study suggests that questions can be a useful tool in leading students to elicit information for new knowledge acquisition for the critical analysis and evaluation of evidence to justify their beliefs about the problem. This in turn provides them with a better understanding of the design problem. On top of that, this study further indicates that the process of identification and clarification of design problem is important in the development of critical thinking skills and social-emotional skills of the students. As such, D&T teachers need to provide students with the time and opportunity to find out the problems by themselves. In addition, teachers are also important role models for students as students may pick up questioning techniques from teacher-student discussions. Lastly, departmental reviews and built-in professional development time for weekly reviews on teaching and learning strategies are necessary for the continual improvement and development of D&T education.

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Author Biography

Wei Leong, Leon LOH

Leon was with the Ministry of Education, Singapore, between 2001 and 2014 where he mostly served as a teacher and Subject Head (D&T) in Singapore secondary schools. Currently, he is with Kyushu University, Faculty of Design, engaging in design education research at tertiary and pre-tertiary level. At the tertiary level, his current research topics include developments of product design education curriculums and quality assurance in design education. At pre-tertiary level, his research topics include a) developing design education curriculums, b) critical thinking and design thinking skills acquisition through design activities and c) learning environment to enhance the quality of design education.

Hwee Mui, Grace KWEK

Grace has been serving as a secondary school teacher in Singapore for 15 years. During this period, she has taken on leadership and mentoring roles such as Subject Head, Head of Department and Lead Teacher. She has received a Master of Design from the University of New South Wales in 2005. Her current work engagements

involve mainly staff development and mentoring programmes. She used to be a member of the Academy of Singapore Teachers (AST) D&T Subject Chapter core team. Her research interest revolves around the development of thinking skills and experiential learning in Design & Technology subject.

Wei Leong, LEE

Lee Wei Leong is a Design & Technology (D&T) Senior Teacher with 14 years of teaching experience in secondary school. Wei Leong holds a Post-Graduate Diploma in Education and a Bachelor Degree (Hons) in Civil and Structural Engineering from National Institute of Education and Nanyang Technological University respectively. He was part of the Academy of Singapore Teachers (AST) D&T Subject Chapter core team between 2011 and 2015. He has also conducted courses for D&T teachers on facilitating students' design thinking skills through effective questioning. He has also been active in professional and academic sharing on topics related to engaging students in the design process during the annual Singapore Design & Technology Educator's Society (DTES) conference for the past 14 years.