EVALUATION METHOD FOR ASSESSING STUDENTS' QUALITY OF CRITICAL THINKING IN THE IDEATION PROCESS THROUGH DESIGN JOURNALS

Leon LOH
Faculty of Design, Kyushu University, Japan

ABSTRACT
This study aims to conceptualise an evaluation method to assess students' quality of critical thinking during the ideation process through design journals. The critical thinking model by Paul and Elder is used as a foundation to create a means to evaluate students' critical thinking. This study creates a case study using the self-study approach as a purposeful sampling strategy. As a self-study approach, the author's experience in conceptualising an evaluation method to assess students' quality of critical thinking documented in the design journal was examined. Using a design journal from a Singapore secondary school, the author presented a method to contextualise the intellectual standards based on teachers' expectations for the design project. The intellectual standards are used to evaluate the reasoning process of the student through the documentation in the design journal.

Keywords: Critical thinking, design education, design and technology, ideation, assessment

1 INTRODUCTION
Design and Technology (D&T) is offered as general education subjects in secondary school education, where students may be exposed to design education such as visual communication design, product design, and textile/fashion. In D&T projects, students often experience and participate in inventive and creative processes to develop new ideas to solve real-world problems. Students are often exposed to unfamiliar contexts when developing new ideas to solve design problems. Students' decision-making process when generating creative ideas is often flawed due to their assumptions that can be influenced by cultural, biological, social, political, theological and historical factors [1]. While facing unfamiliar contexts when designing, students require critical thinking to critique their assumptions and rationalise their decision-making when designing solutions to solve a design problem [2].

In Singapore education, critical thinking and inventive thinking are recognised as vital to helping Singapore's young people strive in the 21st century. Thus, D&T in Singapore aimed to cultivate students' critical thinking through design-and-make projects. In design-and-make projects, students are required to identify design problems, ideate, develop ideas, and realise a working prototype. In the projects, students record their thought processes in design journals. When assessing students' design journals, there is a lack of clear standards and methods to evaluate the quality of students' critical thinking. However, few studies have been done to determine how critical thinking can be systematically assessed through design journals. This study aims to adopt a qualitative research approach to conceptualise an evaluation method to assess students' quality of critical thinking during the ideation process through design journals. Focusing on Singapore D&T, this study will clarify a method to unpack students' critical thinking process in ideation and then assess students' critical thinking through design journals. From the outcomes of this study, teachers can then understand students' reasoning process and provide formative assessments to guide them to correct any flaws in their thinking process.

2 DEFINING CRITICAL THINKING AND EVALUATION OF CRITICAL THINKING
As the objective of D&T is to offer as general education, critical thinking developed through D&T should be transferable across different domains. This study will adopt a generalist approach in exploring the definition for critical thinking. Critical thinking can be conceptualised according to the generalist

(domain-general) and the subject specific (domain specific) approach [3][4][5]. The generalist approach conceptualises critical thinking as a set of skills that may be applied across subjects and disciplines. Although the definitions of critical thinking are varied, most definitions tend to overlap each other considerably [6]. Most definitions of critical thinking include reasoning/logic, judgment, meta cognition, reflection, questioning, and mental process [7]. One of the mainstream concepts of critical thinking was developed by Ennis [8][9][10]. Based on Ennis, critical thinking can be conceptualised through the decision-making process in problem solving. In problem solving, the decisions about belief or action are made through inferences based on observations, information and/or some previously accepted propositions. When making and checking decisions independently, an ideal critical thinker should exercise a group of critical thinking dispositions and abilities where any decision made should be justifiable and able to be articulated to others [11]. In general, measurement of critical thinking skills and dispositions mostly come in the form of test-based assessments.

Paul and Elder provided an alternative model for assessing the quality of critical thinking [12]. The assessment model by Paul and Elder is based on the definition where critical thinking as a disciplined process that actively and skilfully conceptualise, apply, analyse, synthesize, and/or evaluate information gathered from/or generated by observation, experience, reflection, reasoning or communication, to guide one's belief and action [13]. The conceptualisation of critical thinking by Paul and Elder rest on the basis that thinking can be analysed and evaluated by first taking thinking apart and then applying standards to those parts. Paul and Elder explained that whenever thinking occurs, reasoning occurs. This is based on the concept that thinking always occurs for a purpose within a point of view based on assumptions that lead to implications and consequences. Concepts, idea and theories are used to interpret data, facts and experiences in order to answer questions, solve problems and resolve issues. As such, all thinking processes involve generating *purposes*, raising *questions*, using *information*, utilizing *concepts*, making *inferences*, making *assumptions*, generating *implications* and embodying a *point of view*. These eight areas form the eight basic structures of thinking, which Paul and Elder also called the elements of reasoning that are present in reasoning across subjects and cultures. By deconstructing thinking into the elements of reasoning, each element of reasoning may then be assessed.

Paul and Elder suggested that a well-cultivated critical thinker exhibits the following characteristics.

- Raises vital questions and problems, formulating them clearly and precisely.
- Gathers and assesses relevant information and effectively interprets it.
- Generate well-reasoned conclusions and solutions, testing them using relevant criteria and standards.
- Thinks open-mindedly within alternative systems of thought, recognizing and assessing as need be, their assumptions, implications, and practical consequences.
- Communicates effectively with others in figuring out solutions to complex problems.

The formation of these characteristics is based on a conceptual framework where the basic structures of thinking, also called elements of reasoning, can be assessed using a set of standards (also called intellectual standards). Elder and Paul explained that intellectual standards can be conceptualized as standards necessary for making sound judgements and rational understanding [14][15][16][17][18]. The intellectual standards are formed based on the argument that all modern natural languages (such as English, German, Japanese, etc.) provide their users with a wide variety of words that, when used appropriately, serve as plausible guides in the assessment of reasoning. Words such as clarity, accuracy, relevant, significant, logical and so forth are identified as intellectual standard words. Though the focus on determining intellectual standard words is based on the availability in English language, it is hypothesized that similar web of intellectual standard words exist in every natural language, though perhaps with differing nuances. Paul and Elder suggested that there are at least 9 intellectual standards (also called intellectual standard words). The intellectual standards are *clarity*, *accuracy*, *precision*, *relevance*, *depth*, *breadth*, *logicalness*, *significance* and *sufficiency*. Using questions to deconstruct reasoning, a framework of how intellectual standards can be applied to these questions to assess quality of critical thinking is further explained through Paul and Elder's model of critical thinking.

3   RESEARCH METHODOLOGY

3.1   Research questions and method of inquiry

Two key research questions sort to be answered. Firstly, how do we unpack students' critical thinking process during ideation through the design journal? Secondly, upon unpacking students' critical thinking

processes, how do we evaluate the quality of students' critical thinking processes during ideation through the design journals? Through the literature review, Paul and Elder provided a clear structure to unpack reasoning into parts. Without using test-based assessment, Paul and Elder's model allows the quality of reasoning to be assessed using intellectual standards that can be contextualised based on context. With the above considerations, this study adopts the critical thinking model by Paul and Elder.

This study applies a qualitative inquiry strategy based on the principle of purposeful sampling to create a single significant case study. This case study will use a self-study approach as the purposeful sampling strategy. Purposeful sampling is where the cases for study are selected because they are information-rich and can provide deep insights into the phenomenon [19]. As a self-study approach, one's own experience of a phenomenon will be examined. This study will examine the author's experience in conceptualising an evaluation method to assess student's quality of critical thinking documented in the design journal. Singa Secondary School (school name is a pseudonym) in Singapore was selected for this study. Singa Secondary School was selected because the D&T fraternity in Singapore has recognised it for innovation in pedagogy and teaching practices. Though the school has a student profile of a mix of academic abilities, the D&T program has consistently achieved excellent student outcomes.

3.2 Research design and implementation

This study is designed and implemented around Design Journal X done by an upper secondary school student in Design Project A. Design Project A is a major design project that all upper secondary school students in the Express course (between the age of 15 and 16) have to go through in Singa Secondary School. In this project, each student will produce a design journal. Design Project A aims to allow students to apply knowledge and skills learned in D&T to engage in a full design process that starts with a given theme and ends with a working prototype. Teachers are mainly supervisors as students are mainly self-directed during the design process. Students are required to record any forms of idea explorations, research, and evaluation processes related to ideation in the design journals. Thus, it is assumed that each student's thinking and decision-making processes will be recorded in the design journal. Design Journal X was selected based on the rationale that the design journal is a representative sample that reflects the quality of work done by most of the D&T students in Design Project A. The design journal selected for the study is not an outlier in terms of performance.

4 RESEARCH FINDINGS AND DISCUSSIONS

The critical thinking model by Paul and Elder can be applied to all reasonings across different fields, but the importance of some intellectual standards may be different in different fields. Thus, it is necessary to contextualise the intellectual standards within the field and then articulate the intellectual standards that are most important for reasoning. To have a context to contextualise the intellectual standards relevant to the ideation process, the author consulted the D&T teachers involved in Design Project A and collected their expectations of students in generating ideas for this project. Refer to Table 1. These expectations were in line with the assessment rubrics for Design Project A.

Table 1. Teachers' expectations for students during the phase of generating ideas

Teachers' expectations of student in generating ideas
The student generates ideas that can solve the chosen problem.
The student generates as many ideas as they can. This is to ensure that students explore different possibilities in solving the problem. There are no specific expectations on the number of ideas generated.
The student generates ideas to solve the problem in different ways.
The student generates ideas that are practical and probable to solve the chosen problem.
The student elaborates on each idea clearly and logically through sketches and annotations to clarify how the idea can work and how users can use it.
The student generates ideas that are not plagiarized from existing or someone's idea.
The student generates ideas that cater to the needs of the users and also satisfy the design specifications.
The student generates new ideas that has not been seen in the market through their research.
The student evaluates the ideas to identify the potential negative and positive implications or consequences.
The student gives clear and logical reasoning in the choosing the idea(s) to develop further.

Based on teachers' expectations, the author crafted the questions and used them to deconstruct the reasoning process for ideation. In consultation with the D&T teachers, the author drafted the good reasoning traits related to the ideation process. Refer to Table 2. These good reasoning traits will be labelled intellectual standards for good reasoning when generating ideas.

Using the intellectual standards articulated in Table 2 as criteria to assess quality reasoning, the author observed student's reasoning processes during ideation by interpreting the documentation in the Design Journal X. Documentations referred to any form of scribbling, images and sketches in the design journal that constitutes to supporting the reasoning process of the student. In addition, the author also looked out for any parts deemed as faulty reasoning. To increase validity of the interpretations, any queries related to the documentations were clarified with teachers before further interpretations.

The design problem and the design brief below provide the context of what the student is designing.

- Design Problem: *Currently, many homes often face the problem of having too many wires of electronic devices at the desk area at homes where laptops and charging wires are usually kept. Many wires means that they can get entangled easily and therefore it may result in a hassle for the user to untangle the wires. (original text written in the design journal by student)*

- Design Brief: *To design and make a product to help people organize the various wires of their electronic devices so that it helps to prevent the wires from getting tangled and is visually appealing as well. (original text written in the design journal by student)*

Table 2. Intellectual standards for good reasoning articulated to access critical thinking in ideation

Elements of reasoning	Questions to deconstruct reasoning	Intellectual Standards for good reasoning when generating ideas
Purpose	Is the student clear about the purpose of generating ideas to solve the problem?	Display clarity in purpose by showing consistency in addressing the problem when exploring ideas to solve the problem.
Question	Is the student able to ask relevant questions that lead to solving problem when generating ideas? Is the student able to use relevant questions to evaluate the ideas? Is the student able to clarify workability of the ideas using relevant questions? Is the student able to use relevant questions to elaborate the ideas?	Relevant questions are used to generate the ideas. Relevant questions are used to assist student when elaborating the ideas clearly. Relevant questions are used to evaluate the ideas generated. Ability to breakdown the main question into sub-questions to achieve a more precise clarification of the main question with respect to the ideas generated. Relevant sub-questions are used to generate ideas. Relevant sub-questions are used to clarify the ideas generated.
Point of View	From what point of view did student generates the ideas? From what point of view did student evaluates the ideas?	Generating ideas based on other points of view to achieve clarity, relevance, and breadth. Evaluating ideas based on other points of view to achieve clarity, relevance, and fairness.
Assumptions	Are the student's assumptions justifiable and reasonable based on evidence or past experience? Is the student clear about the assumptions that he/she is making?	The workability of the ideas is based on assumption that are justified, reasonable and/or clear.
Information	Does student ultilise relevant information to support his/her claim on the workability of the ideas?	Source of information to support the workability of ideas is relevant, reliable and accurate.
Concepts and Ideas	Is the student able to use concepts to explain the workability of the ideas?	Display clarity, relevance and accuracy in using concepts to justify the workability of the ideas.
Implications and Consequences	Is the student able to anticipate the likelihood of the potential negative and positive implications? Is the student able to clearly and precisely articulate the possible implications and consequences?	Display clarity and logicalness in anticipating the possible implications and consequences of the ideas generated. Display clarity and accuracy in articulating the implications and consequences on the ideas generated.
Inference	Is the student able to make inferences that are justified, reasonable, clear and logical during the process of generating ideas? Is the student able to make inferences that are justified, reasonable, clear and logical when evaluating ideas?	Display justification, reasonability, clarity and logicalness in making inferences when generating the ideas. Display justification, reasonability, clarity and logicalness in making inferences when evaluating the ideas.

With intellectual standards, student's reasoning can be dissected and observed in detail. Each observation that constituted quality reasoning is tagged, and notes are recorded. An example is shown in Figure 1. Short notes or keywords are used as a general "code" to consolidate similar traits related to a particular element of reasoning. The number of times quality reasoning is evident in the documentation are also recorded. Similarly, weak reasonings are also tagged and recorded. From observing and interpreting the documentation, each observation is considered a tag. Table 3 shows the number of tags in the design journal that showed quality and weak reasoning.

The intellectual standards created for this study allowed student's reasoning process to be studied in detail based on the number of tags made through the documentation. However, reading through all the scribbling and sketching can be time-consuming. Nevertheless, if supervising teachers monitor students' progress constantly, it may not be tedious as only bite-size information will be studied.

In this study, it is observed that not all reasoning processes can be articulated in words. Sketches are also essential languages for students to articulate their thought processes during ideation. Thus, teachers should also study students' sketches in detail to highlight instances when questionable concepts and unjustified assumptions are used to create new ideas.

Some concerns and limitations were surfaced when evaluating students' critical thinking. Firstly, evaluations may be hampered when documentations are few in the design journals. This method is only as effective as the content that is documented in the design journal. Secondly, the articulation of the intellectual standards will be varied based on the student outcomes of each project. But the fluidness of

articulating the intellectual standards based on context may also be a strength where teachers can apply this method of evaluating students' critical thinking according to their project setting. Thirdly, the intellectual standards are mainly articulated by the author in consultation with the D&T teachers involved in the project. The intellectual standards applied in this study should undergo verifications by other D&T teachers and/or experts so that the standards can be more robust for evaluating students' critical thinking in ideation. Lastly, the current evaluation method does not provide a detailed analysis of students' level of quality reasoning. The current method can only provide a general indication of whether students exercise quality reasoning. Further research on developing relevant rubrics that compliments the current method to measure the level of quality reasoning is required.
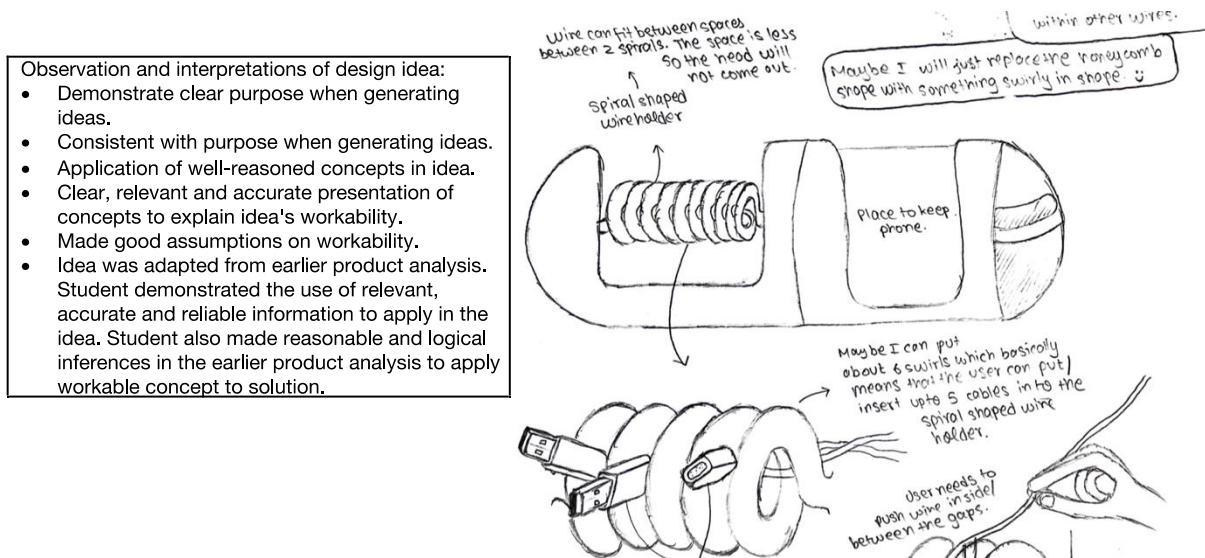

Observation and interpretations of design idea:
- Demonstrate clear purpose when generating ideas.
- Consistent with purpose when generating ideas.
- Application of well-reasoned concepts in idea.
- Clear, relevant and accurate presentation of concepts to explain idea's workability.
- Made good assumptions on workability.
- Idea was adapted from earlier product analysis. Student demonstrated the use of relevant, accurate and reliable information to apply in the idea. Student also made reasonable and logical inferences in the earlier product analysis to apply workable concept to solution.

Figure 1. An example of an observation for good reasoning that is tagged in the design journal

Table 3. Quality of reasoning displayed by student in the design journal when generating ideas

Quality reasoning displayed during ideation based on intellectual standards in Table 2 (described by keywords/shortnotes)	Number of tags where student demonstrated good reasoning based on the intellectual standards for ideation	Associate to which element of reasoning?
Demonstrate clear purpose when generating ideas	23	Purpose
Consistent with purpose when generating ideas	23	
Use relevant question when generating ideas	13	Questions
Use relevant question when evaluating ideas	2	
Seek opinions when generating idea	1	Point of View
Made good assumptions on workability	36	Assumptions
Using relevant information when generating ideas	5	Information
Using reliable information when generating ideas	5	
Using accurate information when generating ideas	5	
Using information to justify ideas	5	
Different source of information when generating ideas	1	
Application of well reasoned concepts in idea	23	Concepts and Ideas
Clear presentation of concepts to explain idea	23	
Anticipate implications and consequences	17	Implications and Consequences
Articulate implications and consequences	7	
Make good inference based on information	4	Inference
Weak reasoning displayed during ideation based on intellectual standards in Table 2 (described by keywords/shortnotes)	Number of tags where student demonstrated weak reasoning based on the intellectual standards for ideation	Associate to which element of reasoning?
Inconsistency with purpose	2	Purpose
Unclear and unjustified assumptions	3	Assumptions
Questionable concepts used in idea	2	Concepts and Ideas
Implications and consequences are not justified	6	Implications and

5 CONCLUSIONS

This study aims to conceptualise an evaluation method to assess students' quality of critical thinking during the ideation process through design journals. Using the critical thinking model by Paul and Elder, the author presented a method to contextualise the intellectual standards based on teachers' expectations for the design project. Using the intellectual standards created, students' reasoning process may be studied and evaluated through the documentation in the design journal. Several limitations were

surfaced. Firstly, limited documentation in the journals will affect the evaluation process. Secondly, more verifications of the intellectual standards by other D&T teachers and experts are required. Lastly, the current method cannot measure students' level of quality reasoning. While the limitations in this study set the themes for future research, the author also intends to apply the current evaluation method to clarify the trend in students' general quality of reasoning in ideation by using a collection of design journals that Singa Secondary School can provide.

ACKNOWLEDGEMENTS

REFERENCES

[1] Spendlove D. The Identification and Location of Critical Thinking and Critiquing in Design and Technology Education. In: Williams, P., Stables, K. (eds) *Critique in Design and Technology Education*, Contemporary Issues in Technology Education, 2017, pp71–86 (Springer, Singapore).

[2] Spendlove D. Challenging Design Thinking in the Classroom. Paper presented at the *29th PATT Conference: Plurality and complementarity of approaches in Design & Technology Education*. Palais du Pharo Marseille – France, April 8th, 2015, pp.373 – 379.

[3] Butler H. A. Assessing critical thinking in our students. In R. Wegerif, L. Li & J. C. Kaufman (Eds.), *The Routledge International Handbook of Research on Teaching Thinking*, 2017, pp.305-314 (London and New York: Routledge).

[4] Davis W. M. An 'infusion' approach to critical thinking: Moore on the critical thinking debate. *Higher Education Research & Development*, 25(2), 2006, pp.179-193.

[5] Moore T. The critical thinking debate: How general are general thinking skills?. *Higher Education Research & Development*, 23(1), 2004, pp.3-18.

[6] Halpern D. F. *Thought and knowledge: An introduction to critical thinking* (5th ed.), 2014 (New York and London: Psychology Press).

[7] Fischer S. C and Spiker V. A. *A framework for critical thinking research and training*, 2000 (Report prepared for the US Army Research Institute)

[8] Ennis R. Critical thinking: a streamlined conception. *Teaching Philosophy*, 14(1), 1991, pp.5-24.

[9] Ennis R. Critical thinking assessment. *Theory into practice*, 32(3), 1993, pp.179-186.

[10] Ennis R. Critical thinking across the curriculum: A vision. *Topoi*, 37(1), 2018, pp.165-184

[11] Ennis R. Critical thinking: A streamlined conception. In Davies M. & Barnett R. (eds), *The Palgrave handbook of critical thinking in higher education*, 2015 (New York: Palgrave).

[12] Paul R. and Elder L. *The miniature guide to critical thinking concepts and tools* (8th ed.), 2019 (Lanham, Boulder, New York and London: Rownman & Littlefield).

[13] Scriven M. and Paul R. *Critical thinking as defined by the national council for excellence in critical thinking*, 1987, Available: http://www.criticalthinking.org/pages/ defining-critical-thinking/766 [Accessed on 2023, 4 March]

[14] Elder L. and Paul R. Critical thinking: Intellectual standards essential to reasoning well within every domain of thought, Part 3. *Journal of Developmental Education*, 37(2), 2013, pp.32-33.

[15] Elder L. and Paul R. *Intellectual standards: The words that name them and the criteria that define them*, 2008 (CA: Foundation for Critical Thinking).

[16] Elder L. and Paul R. Critical thinking: Intellectual standards essential to reasoning well within every domain of thought. *Journal of Developmental Education*, 36(3), 2013, pp.34-35.

[17] Paul R. and Elder L. Critical thinking: Intellectual standards essential to reasoning well within every domain of human thought, Part two. *Journal of Developmental Education*, 37(1), 2013, pp.32-36.

[18] Paul R. and Elder L. Critical thinking: Intellectual standards essential to reasoning well within every domain of human thoughts, Part 4. *Journal of Developmental Education*, 30(3), 2014, pp.3435.

[19] Patton M. Q. *Qualitative research & evaluation methods: Integrating theory and practice* (4th ed.), 2015 (Sage Publications, Inc).