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在設計專題活動中提升界定問題的批判思考能力：以新加坡「設計與科技」為例

摘要

本研究旨於釐清在設計專題活動中，學生對於界定問題的批判思考過程。本研究透過新加坡一所中學的高中學生撰寫的設計日誌，以不同推理要素分析學生的批判思考過程，並評估其推理質量。本研究得出以下結論：首先，使用決策矩陣等決策工具未必能幫助學生實現高質量推理。為提升界定問題時的推理質量，需要更系統化地資訊與證據的收集過程。為了讓學生更有目的地收集資訊或證據，應該在其進行探索前預先訂立問題篩選標準。如此一來，學生收集資訊的能力可獲得提升，從而加深對問題的理解，亦加強學生進行界定問題的決策能力。另外，學生在訂立篩選標準時應聚焦於倫理、重要性、合理性、相關性、情感和可行性等要素。

關鍵詞：設計與科技、批判思考、界定問題、設計教育

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Sharpening Critical Thinking in Design Problem Selection in Design Project: A Perspective Based on Singapore Design and Technology

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Abstract

The current study aimed to identify and clarify students' critical thinking processes when choosing a design problem within the problem identification process when engaging in a design project. Using design journals done by students at upper secondary level in a Singapore secondary school, the study broke down students' critical thinking processes based on various elements of reasoning to assess the quality of reasoning. From this study the following conclusion may be suggested. Firstly, the use of decision-making tools, such as decision matrix, does not necessary enable students to achieve quality reasoning. To enhance quality reasoning when choosing a problem, a more systematic process of information or evidence gathering is necessary. To facilitate purposeful gathering of information or evidence, the selection criteria for choosing a problem should be formed before students are engaged into problem exploration. In this way, it may sharpen students search for information to understand the problem better, which in turn sharpen decision-making in choosing a problem. In addition, when forming selection criteria, it is suggested that students should focus on factors such as ethical, significance, reasonability, relevance, emotions and achievability.

Keywords: Design and Technology, Critical Thinking, Problem Identification, Design Education

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1. Introduction

The framework for 21 Century Competencies (21CC) and Students Outcomes was formalised in 2010 as one of the most significant efforts in 21CC education in Singapore (Tan, 2013; Poon, Lam, Chan, Chng, Kwek & Tan, 2017). Critical thinking and inventive thinking are part of the three broad areas of emerging 21CC, where they are recognised as vital to helping Singapore's young people strive in the 21st century. Since its formalization in 2010, 21CC framework has been infused into the academic curriculum (Tan, Koh, Chan, Pamela & Hung, 2017). However, currently, few studies had been done to understand how critical thinking is being developed systematically through the implementation of pedagogy and practices in Design and Technology (D&T) in schools (Chia & Tan, 2007; Lim, Lim-Ratnam & Atencio, 2013; Loh, Kwek & Lee, 2015, 2017; Tan, 1996).

In the current national syllabuses for all lower secondary and upper secondary D&T courses published by the Singapore Ministry of Education (MOE), there are no clear standards to evaluate students' critical thinking during the process of designing (MOE 2016a, 2016b, 2016c, 2016d). The evaluation standards are mainly to evaluate students' design process. Thus, it is necessary to articulate clear standards to guide students on achieving good critical thinking and also to allow teachers to evaluate students' critical thinking process with clarity.

The current study is part of a research to identifying and clarifying students' critical thinking processes during the problem identification process in D&T projects using Singapore as the context. This study will focus on a specific stage in the problem identification process where students make decisions to choose a design problem to solve. Thus, the main purpose of the study will be to identify and clarify students' critical thinking processes when choosing a design problem to work on further in the design process. The findings will contribute to the understanding of how critical thinking may be systematically developed through D&T and also contribute to the international practices in D&T education.

2. Literature Review

The literature will first attempt to explore the general accepted definitions of critical thinking. This will be followed by reviewing the methods of evaluating critical thinking. The final part of the literature review will determine the working definition of critical thinking for this study.

2.1 Defining Critical Thinking

Conceptualizing critical thinking may be divided by the generalist (domain-general) or the subject-specific (domain-specific) approach (Butler, 2017; Moore, 2004; Davis, 2006). The generalist

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approach conceptualises critical thinking as a set of skills that may be applied across subjects and disciplines (Moore, 2004), whereas, the subject-specific approach believes that critical thinking is closely tied to the subject or domain which it is applied. This is because, the set of critical thinking skills varies among the different domains or situations in which it is applied to (Moore, 2004).

While the definitions of critical thinking remain varied, they tend to have similarities with considerable overlaps (Halpern, 2014; Butler, 2017). Based on a study of literature review on critical thinking by Fischer & Spiker (2000), most definitions of critical thinking include reasoning/logic, judgement, metacognition, reflection, questioning and mental process. Butler (2017) mentioned that most definitions of critical thinking involved the attempt to achieve a desired outcome by thinking rationally in a goal-oriented fashion. Other studies also seemed to have obtained a consensus among policy makers, employers and educators who agreed that critical thinking involves constructing a situation and supporting the reasonings that form a conclusion (Jones, Dougherty, Fantaske, & Hoffman, 1995; Jones et al.,1995). In a way, this "common consensus" on critical thinking definitions tend to tie critical thinking with reasoning.

One of the mainstream concepts of critical thinking was developed by Ennis (1991, 1993, 2018), where "critical thinking means reasonable reflective thinking that is focused on deciding what to believe or do" (Ennis, 1991, p.8). Taking the generalist approach in defining critical thinking, Ennis (1991) considered critical thinking as an important part of problem solving. To provide more clarity on the nature of critical thinking, Ennis (1991) explained the conceptualization of the critical thinking definition through the decision-making process. Decisions about belief or action that generally occur in problem solving should have some basis. This basis may consist of observations, information and/or some previously accepted propositions. A decision is made through the inferences of this basis. Thus, when making and checking decisions independently, an ideal critical thinker should exercise a group of critical thinking dispositions where any decision made should be justifiable and able to be articulated to others (Ennis, 1991, 2015). According to Ennis (2018), other well-known definitions such as the one by Scriven and Paul (1987), as well as definitions by Seigel (1988), Facione (1990), Fisher and Scriven (1997) and Kuhn (2015) are not significantly different from his or from each other.

Scriven and Paul (1987) described critical thinking as a disciplined process that actively and skilfully conceptualize, 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. In other words, critical thinking is a self-directed, self-disciplined, self-monitored and self-correcting thinking process that involves analysing and evaluating thought processes with the intention of improving them (Paul & Elder, 2002, 2019). The conceptualization of the definition of critical thinking by Scriven and Paul (1987) and Paul and Elder (2002, 2019), rest on the basis that

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thinking can be analysed and evaluated by first taking thinking apart and then applying standards to those parts. Paul and Elder (2002) 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 (Paul & Elder, 2002, 2019). Concepts, idea and theories are used to interpret data, facts and experiences in order to answer questions, solve problems and resolve issues (Paul & Elder, 2002, 2019). 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 (Paul & Elder, 2002, 2019). These eight areas form the eight basic structures of thinking, which Paul and Elder (2002, 2019) 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.

2.2 How Critical Thinking can be Displayed and Evaluated?

To further clarify critical thinking, this section reviewed the type of skills and abilities a person may display when critical thinking is exercised. Ennis (1991, 2018) conceptualized a set of general critical thinking dispositions and abilities of an ideal critical thinker. Expanded from the list published in 1991, the latest list included 12 dispositions and 18 abilities (Ennis, 1991, 2018). Mainly using examples from his experience as a juror, Ennis (1991) exemplified and elaborated on each of the dispositions and abilities to explain his conception of an ideal critical thinker. Similarly, Halpern (2014) provided a list of 15 generic skills that a critical thinker will possess. In addition to acquiring skills, it is necessary to develop the attitude or disposition of a critical thinker. Thus, Halpern (2014) included 8 attitudes or dispositions that a critical thinker should exhibit, and just to name a few, willingness to plan, flexibility, and persistence. Among the skills and dispositions suggested by Ennis (2018) and Halpern (2014), some of the overlapping skills and dispositions are the use of existing knowledge, metacognition, understanding and using math, graphs and diagrams for communication, judging creditability of information, making justifiable decisions, open-mindedness, taking a position when there is sufficient evidence and an ability to employ critical thinking skills and dispositions.

In order to exercise critical thinking, possessing the skills may not necessarily mean that critical thinking has been achieved. For example, the ability to analyse evidence and make justified decisions does not mean that a good decision is made based on the quality analysis of the information at hand. In determining if a person has exercised critical thinking, Bailin (1999) emphasized that it is the quality of thinking, not the process of thinking, that differentiate critical thinking from ‘uncritical thinking’. As such, not all thinking activities that aimed at decision making can be considered as

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critical thinking and the quality of thinking has to fulfil a certain level of acceptable standard (Bailin, 1999). In assessing critical thinking skills, many such assessments come in the form of a critical thinking test.

According to Ennis (1993), no subject-specific tests were found but a list of general-oriented-based tests could be consolidated during a study on critical thinking assessment. Almost all the tests were multiple choice test which were good for efficiency and cost, but not comprehensive enough in effective testing for many significant aspects of critical thinking such as being open-mindedness and drawing warranted conclusions cautiously (Ennis, 1993). Ennis (1993) further suggested that open-ended critical thinking tests were necessary for comprehensive assessment, unless appropriate multiple-choice tests were developed. In a recent study, Butler (2017) provided a brief review on the reliability and validity of critical thinking assessments that measure critical thinking skills and those that measure critical thinking dispositions. These tests are used mainly to assess student learning outcomes so as to provide formative feedback to improve instructional methods. In fact, much of these tests may also be seen as an advocate for teaching of critical thinking explicitly rather that implicitly.

While critical thinking skills and dispositions can be assessed using test-based assessment, Paul and Elder (2002, 2019) provided an alternative model for assessing the quality of critical thinking. Paul and Elder (2002, 2019) suggested that a well-cultivated critical thinker should exhibit the following characteristics:

- Raises vital questions and problems, formulating them clearly and precisely
- Gathers and assesses relevant information and effectively interprets it
- Comes to well-reasoned conclusions and solutions, testing them against 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). Intellectual standards can be conceptualized as standards necessary for making sound judgements and rational understanding (Elder & Paul, 2013b; Elder & Paul, 2008). 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 (Elder & Paul, 2008, 2013a; Paul & Elder, 2014). Words such as clarity, accuracy, relevant, significant, logical and so forth are

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identified as intellectual standard words (Elder & Paul, 2008; Paul & Elder, 2013, 2014). Though the focus on determining intellectual standard words are 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 (Elder & Paul, 2008, 2013a; Paul & Elder, 2014). Paul and Elder (2002, 2019) suggested that there are at least 9 intellectual standards (also called intellectual standard words), recently expanded to 10. The intellectual standards are clarity, accuracy, precision, relevance, depth, breadth, logicalness, significance and sufficiency (Paul & Elder, 2002, 2019). Using questions to deconstruct reasoning, a framework of how intellectual standards can be applied to these questions to assess quality of critical thinking has been further explained by Paul and Elder (2002, 2019), and Elder and Paul (2008).

2.3 Adopting a Model to Assess Critical Thinking

The different ways of defining critical thinking seems to be just different ways of cutting the same pie. The main concept of critical thinking process revolved around the process of reasoning. With this assumption, Paul and Elder provided a clear structure to unpack reasoning into parts. Without the need for a standardized critical thinking assessment test, Paul and Elder had also created a model to allow the quality of reasoning to be assessed using the intellectual standards, through questioning techniques. Furthermore, this model is flexible in application across different subject areas and provides a great potential for the application in this study. With above considerations, the current study adopts the definitions of critical thinking conceptualized by Paul and Elder (2002, 2019) and Elder and Paul (2008), and at the same time, attempts to apply the concept of elements of reasoning and intellectual standards to achieve the objectives of this study.

3. Research Question and Methodology

3.1 Research Question

This study sought to answer the following main question.

- After an initial brainstorming and exploration of problems, how do students exercise critical thinking to choose a problem to work on further in the design process?

3.2 Research Approach and Method

The current study employed a qualitative research methodology to gain insights on students' application of critical thinking to choose a design problem. The method used for the current study

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was the collective case study, as described by Goddard (2010). The current study will be conducted within a single site, which is a government secondary school in Singapore. The considerations for choosing the site are shown in Table 1. Singa Secondary School (the school name used is a pseudonym), was identified as a potential site for the study. The selection of Singa Secondary School was based on the following reasons in Table 2.

Table 1
Criteria for choosing a study site

	Criteria for Selection of Study Site
1.	School should be recognised to implement a progressive D&T programme
2.	D&T teachers are active in professional sharing in the Singapore D&T fraternity.
3.	Profile of students studying D&T consists of a mix of academic abilities

Table 2
Reason for choosing the current study site

	Reasons to select Singa Secondary School as Study Site
1.	As a pilot school for implementing Framework for 21CC in 2010, the school will have more experience with the review and implementation of pedagogy and practices to develop critical thinking.
2.	Widely recognised by the D&T fraternity in Singapore, for the last 15-17 years, for innovation in pedagogy and teaching practices, and the ability to achieve excellent student outcomes. D&T teachers from different parts of Singapore often seek opportunities to visit the school to learn from the teachers.

3.3 Objects of Study

The objects, or cases, for this study are the design journals done by upper secondary students in Design Project A for a D&T Express course. 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 Design Project A, students will complete the project on their own. Each student will produce a design journal. As such, each case for this study is represented by a design journal done by one student.

The main purpose of Design Project A is to allow students to exercise their knowledge and skills learned in D&T up till the point of Design Project A to engage in a full design process that starts with a given theme and ends with a proposed working prototype. In this project, students take main control of the design process as teachers supervise. The given theme for Design Project A differs yearly, but the tasks required, and assessment criteria are consistent.

In Design Project A, students are required to record any forms of explorations, research, ideation, experimentation and evaluation processes related to problem identification, ideation, idea development and prototyping into the design journals. Thus, the used of design journals as objects of study is based on the assumptions that design journals are a detailed collection of students' thinking and decision-making processes during the design process. In the selection of design journals for study, the following considerations were made. (Refer to Table 3)

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Table 3
Considerations for design journals selections as study cases

	Considerations for Selecting Design Journals as Cases
1.	The design journals should be done by students who were conscientious in completing their work. This is to ensure that any deficiency in their performance in the design journals are due to their abilities rather than the lack of effort.
2.	The design journals should be done by students who had gone through similar D&T curriculum before attempting Design Project A. This is to reduce the disparity of student performance due to the difference in terms of content knowledge and skills.
3.	The design journals should be representative samples that reflect the quality of work done by majority of the D&T students in Design Project A. The design journals selected for study should not be the outliers in terms of performance.

In a pilot school for 21CC, the D&T department had reviewed the curriculum for the lower and upper secondary D&T Express course. Started in 2012, critical thinking is taught more explicitly in lower secondary D&T. Thus, upper secondary students engaging in the Design Project A from 2014 onward would have gone through a similar D&T programme starting from lower to upper secondary. Using available archives of design journals produced between 2014 and 2016, 15 cases based on the design journals that were supervised by two teachers were selected for this study. (Refer to Table 4)

Table 4
The number of journals used for study between 2014 and 2016

Year:	No. of Archived Journals Used	Supervised by:
2014	8	Teacher A
2015	1	Teacher A
2016	6	Teacher B

Based on class deployment, the academic profile of students supervised by the two teachers were similar. Throughout the year, it is a practice in the school that all D&T teachers will often share and discuss about teaching and learning, and students' progress for all levels (secondary 1 to 4) of D&T learning. These forms of meeting provide professional development for all D&T teachers and also reach consensus on what to expect for student outcomes for each level. Though the selected design journals for this study were supervised by two D&T teachers, the disparity in the quality of supervision, teaching and student academic abilities related to this study were considered to be minimum.

3.4 Research Design

The primary set of data was collected via students' documentations in the design journals. The scope of data collection covers students' documentation during the process of decision making to select a design problem. Students' documentations will include written and printed text, sketches and photos. The general process undertaken by students during the process in focus can be described as

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follow. The process of decision making to select a design problem comes after the brainstorming process to explore a range of possible problems related to the given theme. When making a decision to select a problem to work on further, students would evaluate the various problems identified during the brainstorming process.

To design a method to interpret the students' documentation, firstly, the author consulted the teachers and collected the expectations for students to achieve in the process within the scope of study (refer to Table 5). These expectations were in line with the assessment rubrics for Design Project A. Though the critical thinking model by Elder & Paul (2008) can be applied to all reasonings across different fields, the importance of some intellectual standards may be different in different fields. Thus, it is necessary to contextualize the intellectual standards within the field and then to articulate the intellectual standards that are most important for reasoning (Elder & Paul, 2008). Table 5 and 6 provided the context for the author to contextualize the intellectual standards relevant to the current study.

Based on Table 5, questions were used to deconstruct reasoning for the decision-making process in selecting a problem and then after, intellectual standards were applied to answer these questions (Elder & Paul, 2008). By answering the questions, the intellectual standards essential to good reasoning related to the processes in the current study can be articulated (refer to Table 6). Using Table 6, the author was able to observe students' critical thinking processes by interpreting the documentations in the design journals. To increase validity of the interpretations, any queries related to the documentations were clarified with teachers before further interpretations. In addition, all observations were provided to the D&T teachers for clarification so that any misinterpretations could be corrected.

Table 5
Teachers' expectations for students during the process of choosing a problem

Teachers' expectations of student in choosing a problem to work on
Student is encouraged to choose a problem of their interest, from a context that they are familiar with, or easy access to research for information.
Student needs to give a reasonable and logically explanation for the rationale of choosing the problem.
Student needs to choose a problem that will make a positive impact to people' lives.
Student needs to choose a problem that can be solved with a physical product.

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Table 6

Deconstructing reasoning and articulating intellectual standards for good reasoning when choosing a problem

Elements of Reasoning when Choosing a Problem	Questions to deconstruct reasoning	Intellectual Standards for good reasoning in Choosing a Problem
Purpose	□ Is the student able to adopt realistic purposes and goals when choosing a problem? □ Is the student able to choose a problem based on significant purposes and goals?	□ The ***achievability*** of the problem is ***clearly*** articulated. □ Display ***clarity*** in purpose by choosing a problem related to the theme. □ The significance of solving the chosen problem is ***justified*** and ***clearly*** articulated.
Questions	□ Is the student able to use relevant questions to evaluate the problems?	□ Formulate ***relevant*** and ***clear*** questions and apply them to evaluate the problems that lead to the chosen problem.
Point of View	□ From what point of view do student use to choose the problem?	□ The problem is chosen based on other points of view to achieve ***fairness*** and ***clarity***.
Information	□ To what extend is the student's decision on the chosen problem supported by relevant and fairly gathered information?	□ The evaluations of the different problems are supported by ***reliable*** and ***adequate*** source of information. □ The decision for choosing a problem is supported by ***reliable*** and ***adequate*** source of information.
Concepts and Ideas	□ Are the key ideas and concepts that guide students' reasoning to choose a problem clear, accurate or deep?	□ Display ***clarity*** and ***depth*** in concepts and ideas used to ***justify*** research conclusions.
Assumptions	□ Are the student's assumptions justifiable and reasonable based on evidence or past experience when choosing the problem?	□ The reasons given for choosing a problem based on the student's assumptions which are ***justified*** and ***clear***.
Implications and Consequences	□ Is the student able to clearly and precisely articulate the possible implications and consequences in choosing the problem?	□ The reasons given for choosing a problem is articulated ***clearly*** and ***logically*** based on the implications and consequences in choosing the problem.
Inference	□ Is the student able to make inferences that are reasonable, clear and logical to support the problem chosen?	□ Inferences and interpretations made to support the problem chosen are ***reasonable***, ***clear*** and ***logical***.

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3.5 Research Implementation

During the implementation of the study, to gain a holistic view, the documentations in each design journal were first studied to understand the processes embarked by students to select a problem. Then after, using Table 6 to interpret the documentations, observations of each student's good reasonings and weak reasonings with respect to each of the elements of reasoning were recorded. After all the 15 design journals were interpreted and observations recorded, common and different patterns in students' reasoning for each element of reasoning could be identified and clarified.

4. Findings: Critical Thinking in Choosing a Problem

Before students make decision to choose a problem, students will explore a range of possible problems that are related to the theme. During the problem exploration process, students mainly focus on brainstorming and exploring relevant problems (Loh, 2020). Students did not conduct any forms of evaluation on the problems that might assist their decision-making process in choosing a problem. When making a decision to select a problem after problem exploration, students were free to use any methods they had learned to evaluate their choice of problems and assist their decision-making processes.

4.1 Observations of Good Reasoning

A general observation in the journals during the process of choosing a problem can be described as follow. It was evident that nine students used a decision matrix to assist their decision making in choosing a problem (refer to Figure 1). In a typical decision matrix, the left most column of the decision matrix are criteria set by students and the top row of the matrix are the headings of problems identified during problem exploration. Students would evaluate all the problems based on the criteria they set. A score will be given to each problem against each criterion. The scoring system is usually based on the number of problems (n) available. With the lowest ranked problem given 1 point and the highest given n points. Then after, the total score for each problem is tabulated in the lowest row of the matrix.

For students using the decision matrix, seven of the students chose the problem with the highest score. While the other two students could not decide on their choice of a problem went on to seek teacher's opinion. The teacher then advised the two students to conduct more research for those problems in the decision matrix with higher scores so that it may help them in their decision making.

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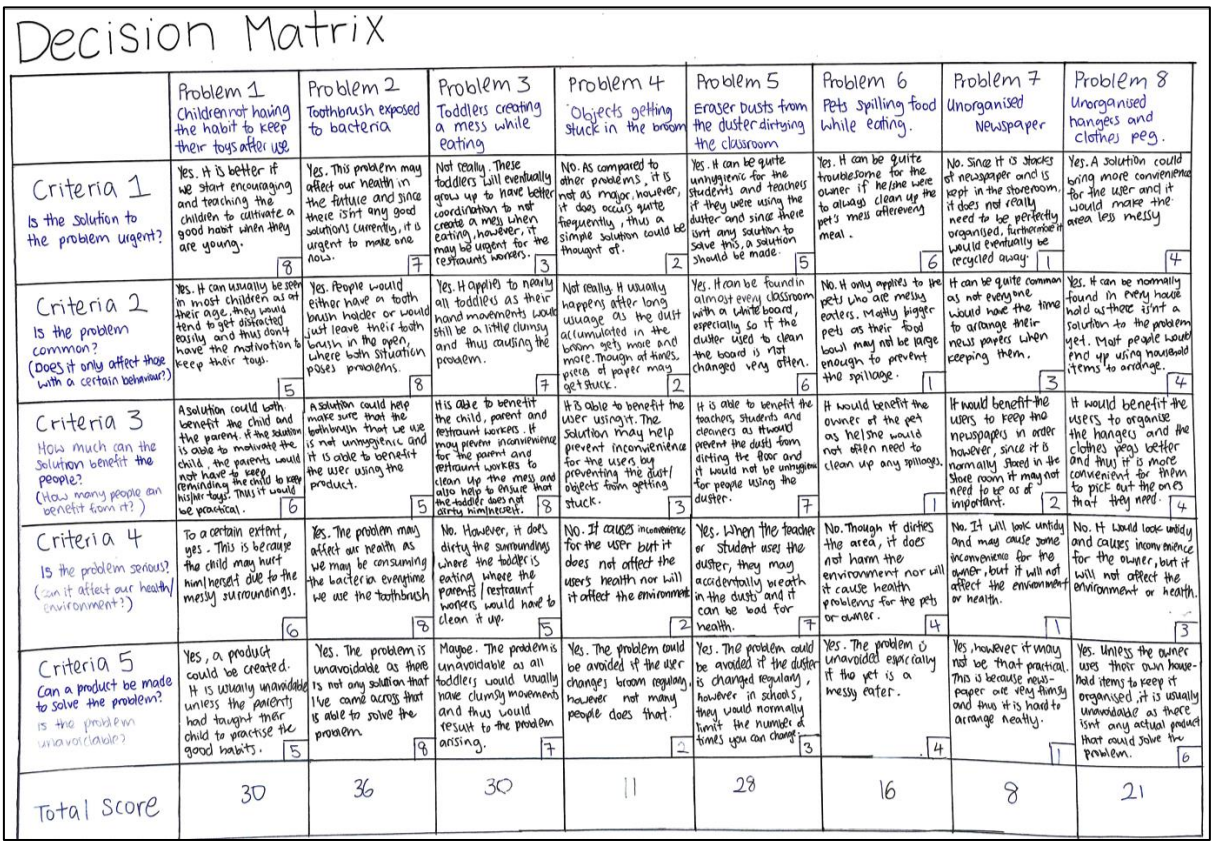
In six students who did not use the decision matrix, five of them provided reasons in their journals to explain their choice of the chosen problem. But one of student did not provided any reasons as to why she chose the problem. But this particular student did provide reasons for modifying her chosen problem immediately after choosing the problem.



Decision Matrix

	Problem 1 Children not having the habit to keep their toys after use	Problem 2 Toothbrush exposed to bacteria	Problem 3 Toddlers creating a mess while eating	Problem 4 Objects getting stuck in the broom	Problem 5 Eraser dusts from the duster dirtying the classroom	Problem 6 Pets spilling food while eating.	Problem 7 Unorganised Newspaper	Problem 8 Unorganised hangers and clothes peg.
Criteria 1 Is the solution to the problem urgent?	Yes. It is better if we start encouraging and teaching the children to cultivate a good habit when they are young. 8	Yes. This problem may affect our health in the future and since there isn't any good solutions currently, it is urgent to make one now. 7	Not really. These toddlers will eventually grow up to have better coordination to not create a mess when eating, however, it may be urgent for the restaurants workers. 3	No. As compared to other problems, it is not as major, however, it does occurs quite frequently, thus a simple solution could be thought of. 2	Yes. It can be quite unhygienic for the students and teachers if they were using the duster and since there isn't any solution to solve this, a solution should be made. 5	Yes. It can be quite troublesome for the owner if he/she were to always clean up the pet's mess afterevery meal. 6	No. Since it is stacks of newspaper and is kept in the storeroom, it does not really need to be perfectly organised, furthermore it would eventually be recycled away. 1	Yes. A solution could bring more convenience for the user and it would make the area less messy 4
Criteria 2 Is the problem common? (Does it only affect those with a certain behaviour?)	Yes. It can usually be seen in most children as at their age, they would tend to get distracted easily and thus don't have the motivation to keep their toys. 5	Yes. People would either have a tooth brush holder or would just leave their toth brush in the open, where both situation poses problems. 8	Yes. It applies to nearly all toddlers as their hand movements would still be a little clumsy and thus causing the problem. 7	Not really. It usually happens after long usuage as the dust accumulated in the broom gets more and more. Though at times, piece of paper may get stuck. 2	Yes. It can be found in almost every classroom with a white board, especially so if the duster used to clean the board is not changed very often. 6	No. It only applies to the pets who are messy eaters. Mostly bigger pets as their food bowl may not be large enough to prevent the spillage. 1	It can be quite common as not everyone would have the time to arrange their news papers when keeping them. 3	Yes. It can be normally found in every house hold as there isn't a solution to the problem yet. Most people would end up using household items to arrange. 4
Criteria 3 How much can the solution benefit the people? (How many people can benefit from it?)	A solution could both benefit the child and the parent. If the solution is able to motivate the child, the parents would not have to keep reminding the child to keep his/her toys. Thus it would be practical. 6	A solution could help make sure that the toothbrush that we use is not unhygienic and it is able to benefit the user using the product. 5	It is able to benefit the child, parent and restaurant workers. It may prevent inconvenience for the parent and restaurant workers to clean up the mess and also help to ensure that the toddler does not carry maintenance. 8	It is able to benefit the user using it. The solution may help prevent inconvenience for the users by preventing the dust/ objects from getting stuck. 3	It is able to benefit the teachers, students and cleaners as it would prevent the dust from dirting the floor and it would not be unhygienic for people using the duster. 7	It would benefit the owner of the pet as he/she would not often need to clean up any spillages. 1	It would benefit the users to keep the newspapers in order however, since it is normally stored in the store room it may not need to be as of important. 2	It would benefit the users to organise the hangers and the clothes pegs better and thus it is more convenient for them to pick out the ones that they need. 4
Criteria 4 Is the problem serious? (Can it affect our health/ environment?)	To a certain extent, yes. This is because the child may hurt him/herself due to the messy surroundings. 6	Yes. The problem may affect our health as we may be consuming the bacteria everytime we use the toothbrush 8	No. However, it does dirty the surroundings where the toddler is eating where the parents / restaurant workers would have to clean it up. 5	No. It causes inconvenience for the user but it does not affect the users health nor will it affect the environment 2	Yes. When the teacher or student uses the duster, they may accidentally breath in the dusts and it can be bad for health. 7	No. Though it dirties the area, it does not harm the environment nor will it cause health problems for the pets or owner. 4	No. It will look untidy and may cause some inconvenience for the owner, but it will not affect the environment or health. 1	No. It would look untidy and causes inconvenience for the owner, but it will not affect the environment or health. 3
Criteria 5 Can a product be made to solve the problem? Is the problem unavoidable?	Yes, a product could be created. It is usually unavoidable unless the parents had taught their child to practise the good habits. 5	Yes. The problem is unavoidable as there is not any solution that I've came across that is able to solve the problem 8	Maybe. The problem is unavoidable as all toddlers would usually have clumsy movements and thus would result to the problem arising. 7	Yes. The problem could be avoided if the user changes broom regularly, however not many people does that. 2	Yes. The problem could be avoided if the duster is changed regularly, however in schools, they would normally limit the number of times you can change 3	Yes. The problem is unavoidable especially if the pet is a messy eater. 4	Yes, however it may not be that practical. This is because news-paper are very flimsy and thus it is hard to arrange neatly. 1	Yes. Unless the owner uses their own house-hold items to keep it organised, it is usually unavoidable as there isn't any actual product that could solve the problem. 6
Total Score	30	36	30	11	28	16	8	21

Figure 1. An example of decision matrix to evaluate all problems against criteria.

Based on the 15 design journals, the critical thinking processes exercised by students to choose a problem can be broken down by elements of reasoning. By applying the intellectual standards articulated in Table 6, the quality of students' critical thinking could be assessed through the documentations in their design journals. In this section, Table 7 consolidates the observations of common and different patterns of good reasoning exercised by students. When necessary, the observations may be accompanied by an example extracted from part of a design journal and be presented via a figure indicated at the end of the respective observations.

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Table 7

Observations of good reasoning when choosing a problem

Elements of Reasoning during Choosing a Problem	Observations of Good Reasoning in Choosing a Problem [1,2] [1]The number in the bracket [ ] represents number of design journals with similar observation [2] When necessary to present the observation clearer, an example from a journal may also be provided as a figure
Purpose	□ One student was observed to have decided on the problem based on the accessibility for research, her own willingness to try, the time and cost needed to invest in the research and current available solutions in the market. The reasons given are ***clear***, ***logical***, ***achievable*** and ***realistic***. [1] (refer to Figure 2) □ A handful of students gave ***clear*** and ***logical*** reasoning to ***justify*** the significant positive impact of solving the problems they have chosen. [4] (refer to Figure 3) □ More than half of the students evaluated all the problems based on frequency of occurrence, number of people impacted, urgency, importance and/or personal conviction of solving the problem. The evaluations were ***clear*** and ***logical*** to ***justify*** the significant of solving the problem. [8] (refer to Figure 1) □ One student inserted a criterion to evaluate the ***achievability*** of all the problems based on whether a product can be designed to solve the problem. The evaluations for this criterion were articulated ***clearly*** and ***logically***. [1] (refer to Criteria 5 found in Figure 1) □ One student took an unusual path in choosing a problem based on ***significance***. Initially, this student did not provide any reasons to explain why a problem was chosen. But based on her conversation with stakeholders, she realised that the problem that she focused on was not significant for the stakeholders. Instead, the stakeholders provided some other problems that are more crucial to solve. Thus, led to her modifying the initial problem. As a final chosen problem, this student was able to ***justify*** the choice of problem based on the creating positive ***significant*** impact to stakeholders. [1] (refer to Figure 4) □ As one of the evaluation criteria, one student evaluated the ***significance*** of the problem ***clearly*** based the frequencies of the problems that he, or his families and friends faced commonly. [1]
Questions	□ A handful of students used ***relevant*** questions as criteria to guide their evaluation of problems in order to decide on one problem. [5] (refer to Figure 1)
Point of View	□ One student sought ***relevant*** viewpoints from teacher to verify the problems identified. Through this, she got to know that there are existing good solutions are available for one of the problems she hoped to choose. Student had displayed ***fairness*** in accepting opposing viewpoints that are not in favour of her findings. Through seeking ***relevant*** viewpoints, she later to identify another possible related problem related to the same context. [1] (refer to Figure 5) □ One student sought ***relevant*** viewpoints from friends to evaluate the viability of solving the problem. [1] □ One student sought ***relevant*** viewpoints from dog owners (stakeholders) with regards to her chosen problem and realized that the chosen problem is not that significant. She managed to ***clarify*** the more significant aspects of the problem faced by the stakeholders related to the same context. [1] (refer to Figure 4) □ Some students displayed ***flexibility*** by seeking other viewpoints, such as from teachers, when they faced difficulties in choosing the problem. [3]
Information	□ Student gathered ***adequate*** information through stakeholders to claim that none of the stakeholders are willing to assist her in conducting research to understand the problem. Student stated this information ***clearly*** as evidence to support her decision of not choosing a problem. [1] (refer to Figure 6)

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Concepts	□ More than half of the students displayed ***clarity*** in applying the concept of objective decision-making by using criteria and points via a decision matrix. [9] (refer to Figure 3) □ For some instances, students were able to think ***deeply*** about the concepts used as criteria to evaluate the problems in the decision matrix. This was evident as students were able to articulate most, but not all, of their evaluations of the problems ***clearly*** and ***with relevance*** to the respective criteria. [8] (refer to Figure 1)
Assumptions	□ In general, students were able to articulate their assumptions ***clearly*** and ***logically*** to ***justify*** their reasons for choosing the problem. [14] (refer to Figure 7) □ Two students made decisions in selecting problems based on assumptions that were ***justified*** by information gathered through seeking other points of view. [2] (refer to Figure 4)
Implications and Consequences	□ When making the decision to choose a problem, one student articulated ***clearly*** the potential negative consequences if the problem was not addressed. [1] (refer to Figure 8) □ Most students articulated the implications and consequences ***clearly*** and ***logically*** to support their decisions in choosing a problem. [13] (refer to Figure 7)
Inferences	□ A few students who gathered information from teacher, friends and/or related stakeholders were able to articulate their inferences of the information ***accurately*** to ***justify*** their problem selection or decision-making process that leads to next course of action to select a problem. [5] (refer to Figure 9)

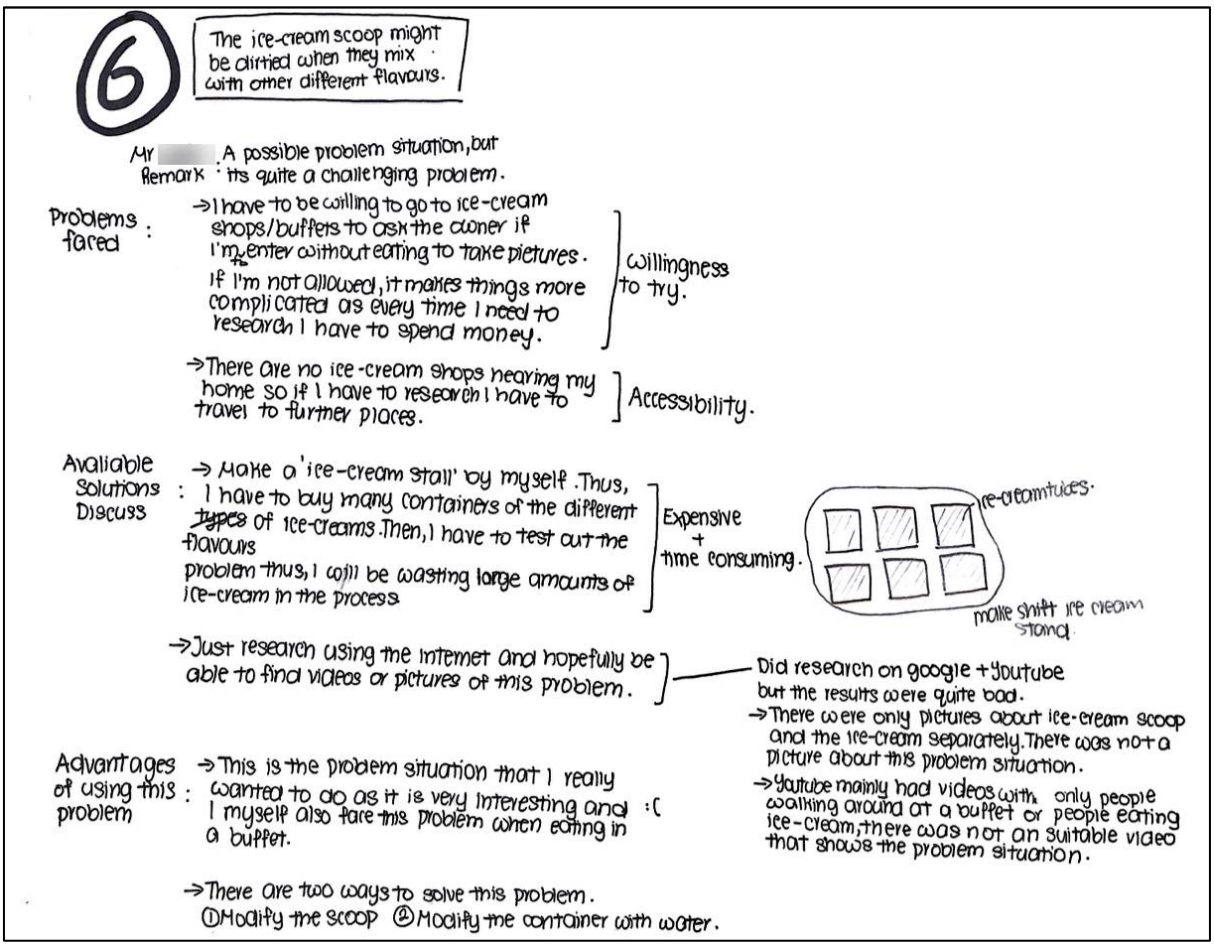

Figure 2. An example of a student who did not use a decision matrix but displayed purposeful selection of problem.

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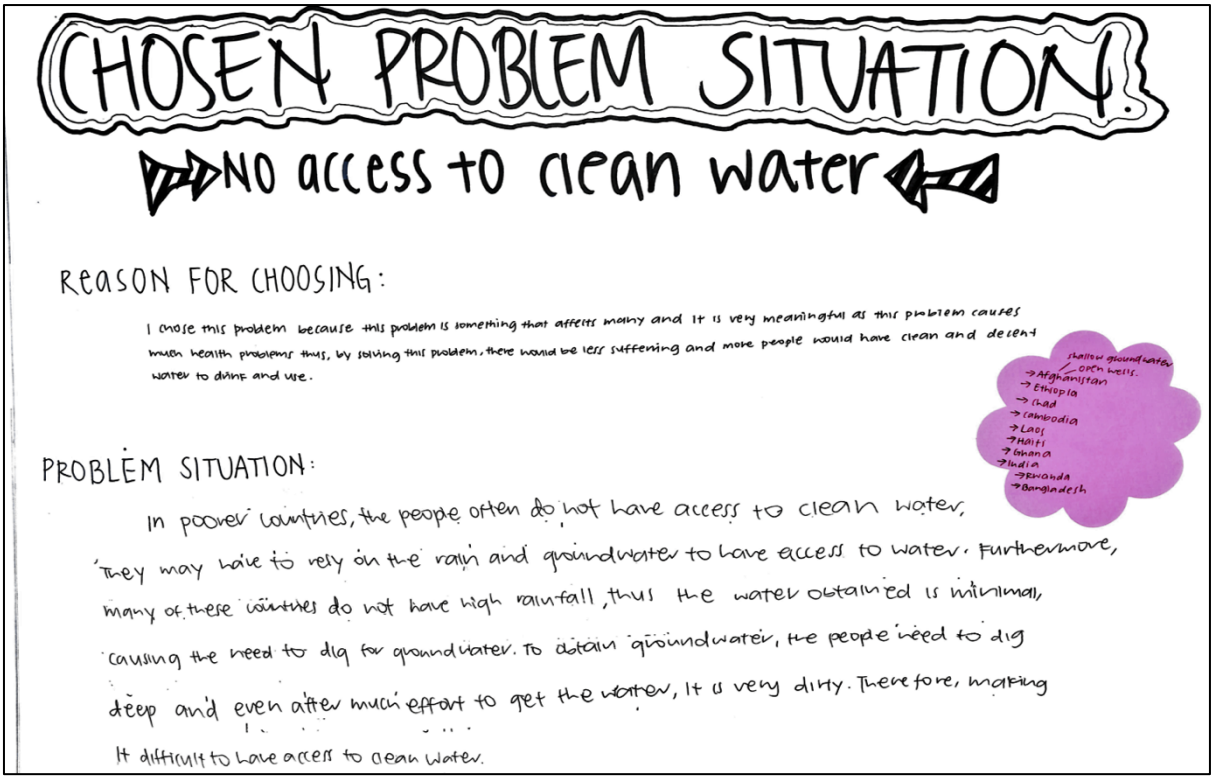

Figure 3. An example of a student who displayed clear and logical reasoning in justifying significantly positive impact for solving the chosen problem.

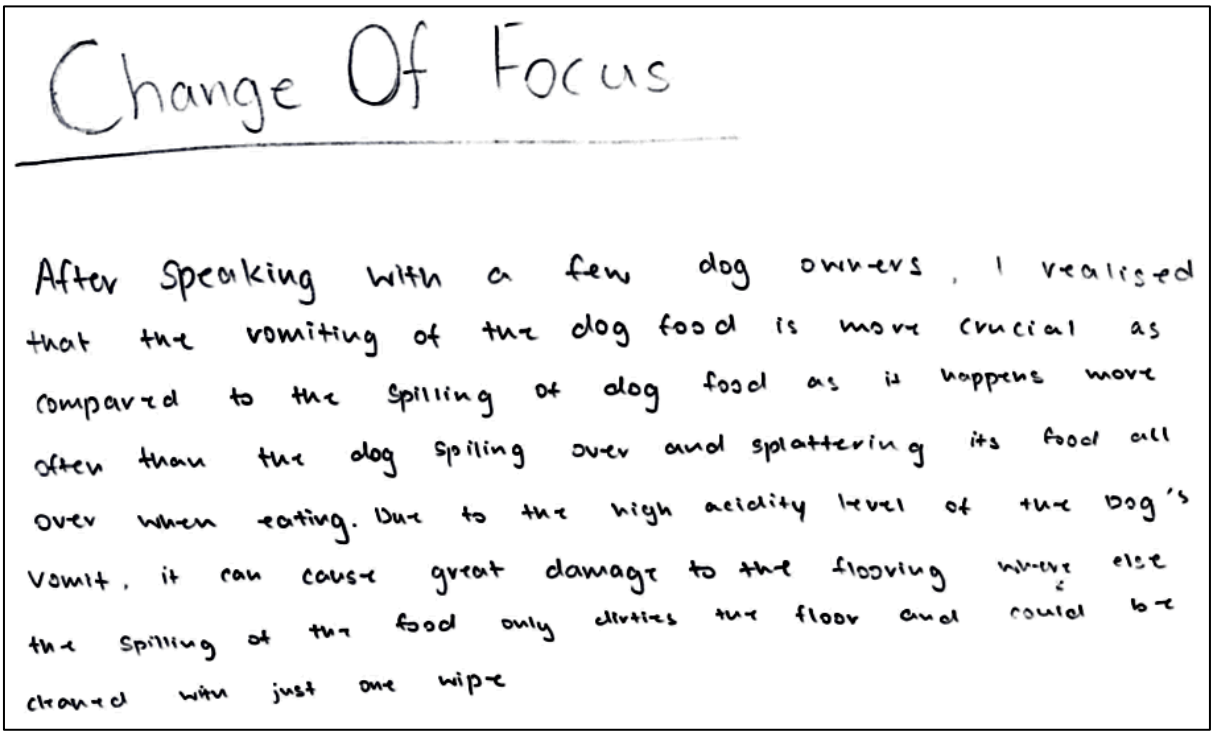

Figure 4. An example of a student displaying the willingness to modify her purpose in solving a problem based on other significance identified through seeking other points of view.

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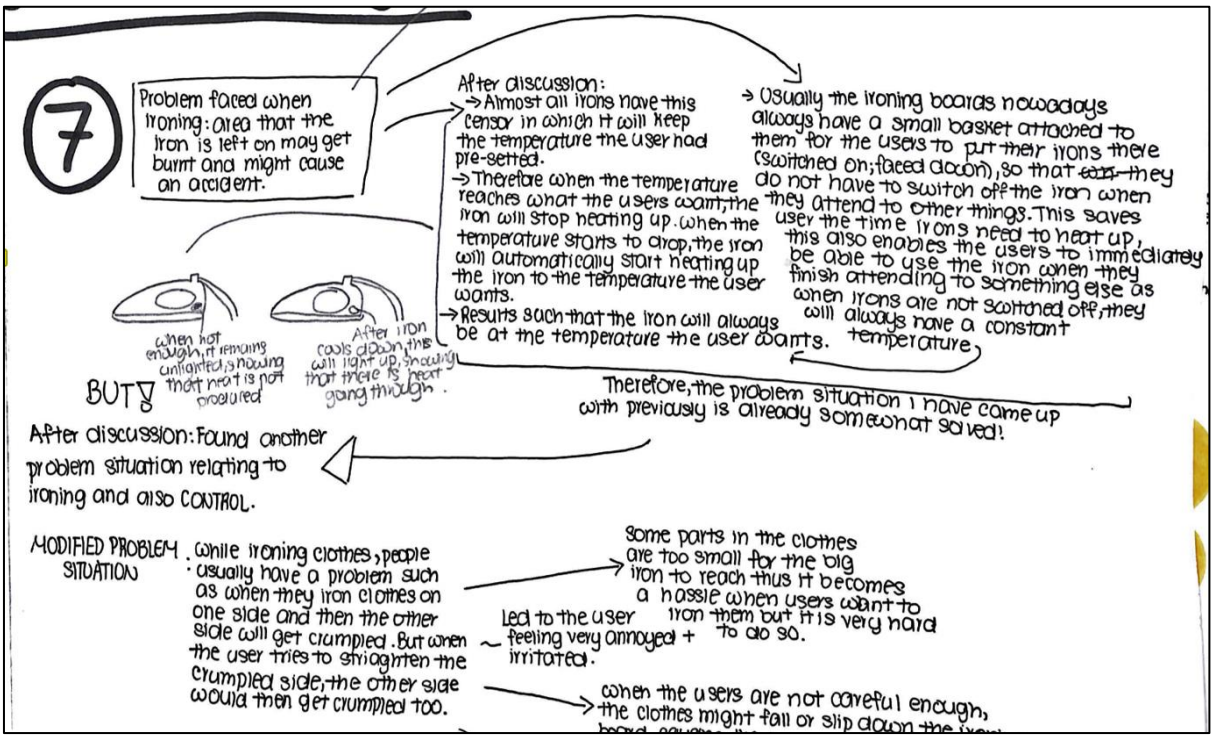

Figure 5. An example of a student who documented the outcomes of the discussion with teacher who gave opposing viewpoints which lead to the modification of problem.

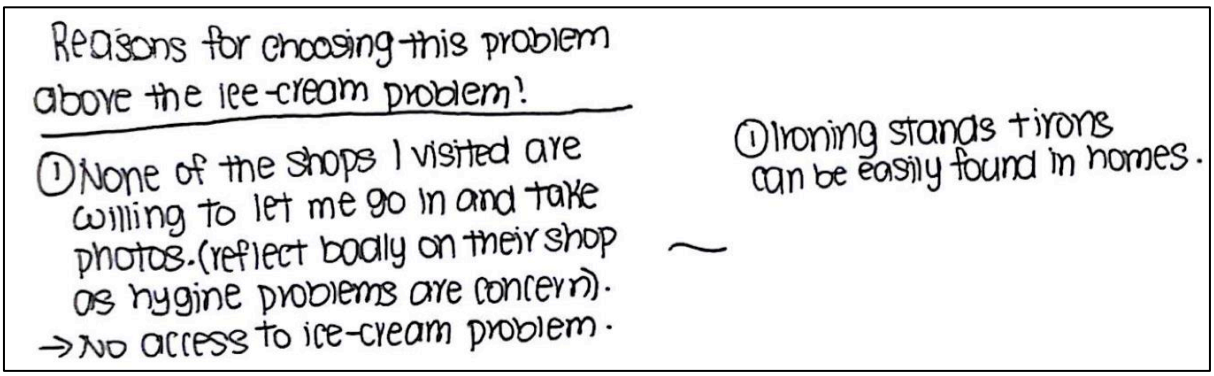

Figure 6. An example of a student who gathered adequate information before making a decision in her problem selection.

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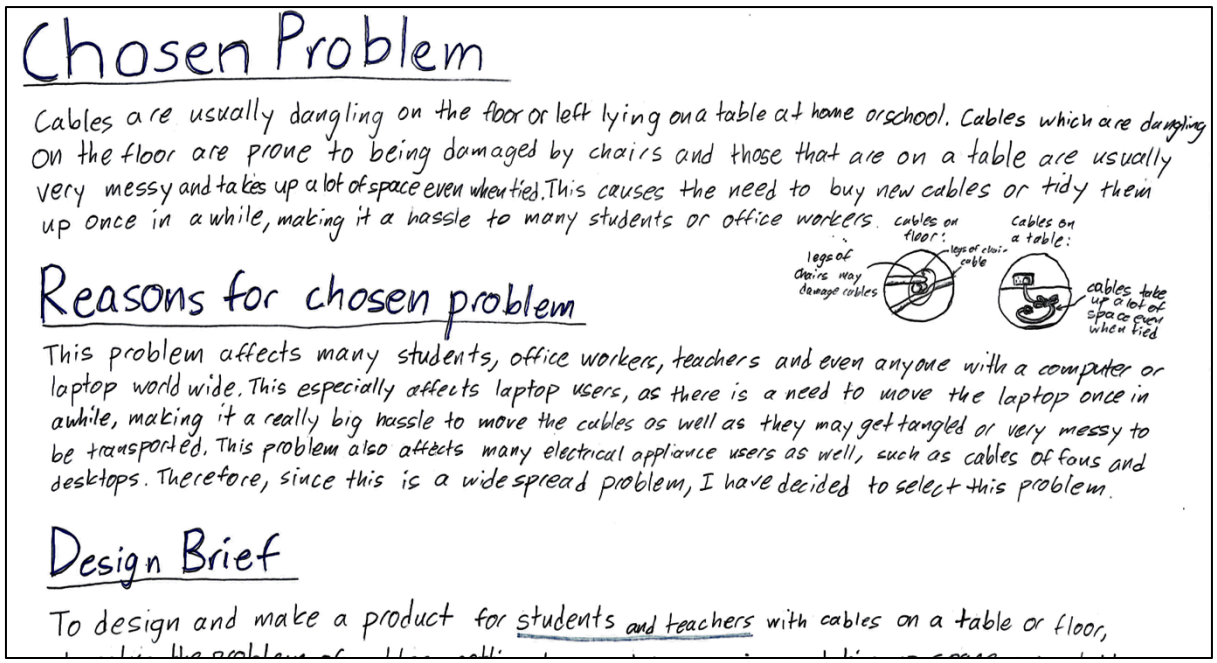

Figure 7. *An example of student being able to articulate his assumptions clearly and logically to form a decision.*

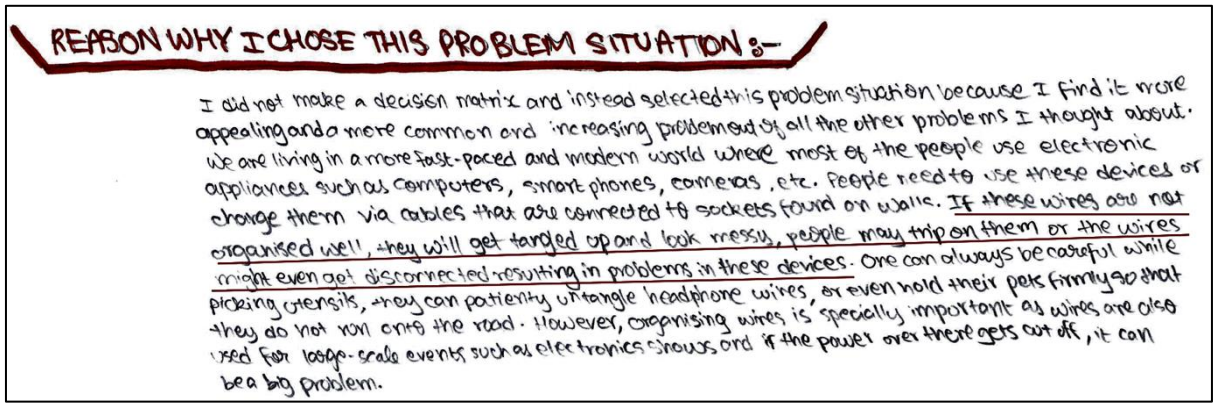

Figure 8. An example of a student articulating clearly the potential negative consequences.

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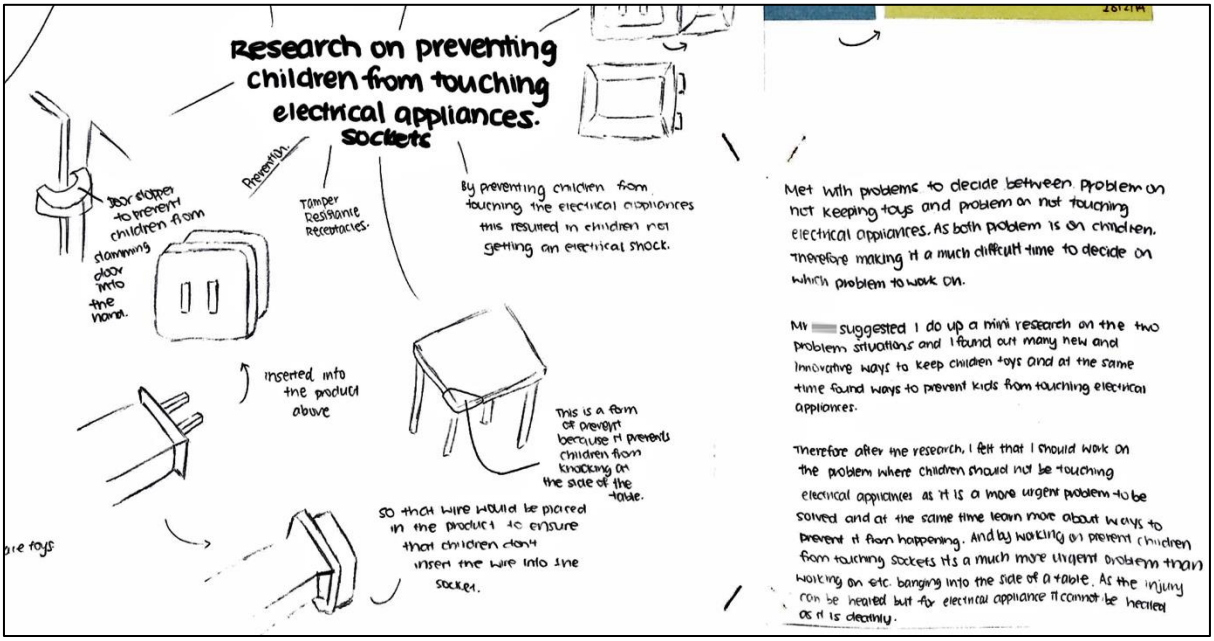
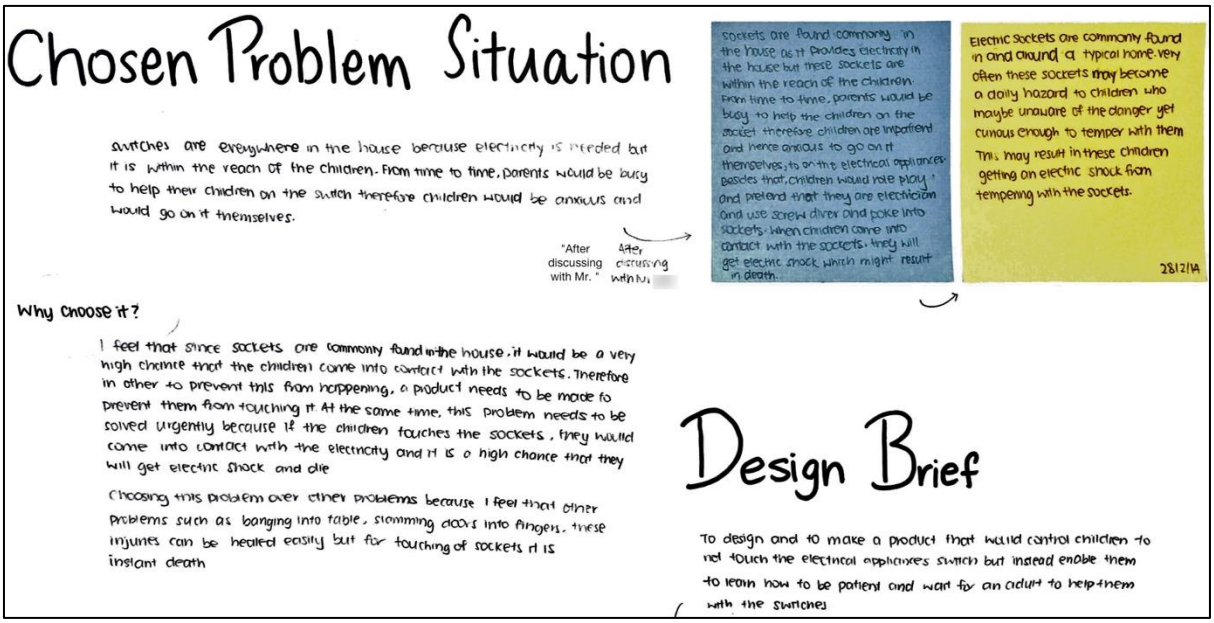


(a)



(b)

Figure 9. (a) An example of student who was able to articulate her inferences clearly based information gather during a discussion with teacher that called for the need for further research before choosing a problem; (b) Same student later was able to further articulate the problem clearly based on what seems to be a discussion with teacher but the decision to choose the problem is mainly based on her assumptions.

4.2 Observations of Weak Reasoning

Using Table 6, areas of weak reasonings displayed by students can also be observed based on the documentations in the design journals and can be presented in Table 8. In general, most students were able to articulate clearly and logically to justify their assumptions towards their decision-making

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processes in the selection of problem. But one major issue observed was that, although students can clearly and logically justify their assumptions, most of the assumptions made were not accurately justified with evidence. In other words, very often there was no evidence provided to support their assumptions. Thus, almost all fourteen students did not support their decision of choosing a problem based on any form of data or information as evidence. This was especially evident for students who did not use the decision matrix. Although they have stated their reasons in choosing a problem, but nothing was provided in the journals that support their reasons. Although more than half of the students used the decision matrix as a structure to assist them in their decision-making processes, their evaluations of each criteria were mostly based on their own assumptions. Thus, students may have gone through the process of systematic decision-making, but the quality of reasoning during the decision-making process was weak.

Table 8

Observations of weak reasoning when choosing a problem

Elements of Reasoning during Understanding the Chosen Problem	**Observations of Weak Reasoning in Choosing a Problem [1,2]** [1]The number in the bracket [ ] represents number of design journals with similar observation [2] When necessary to present the observation clearer, an example from a journal may also be provided as a figure
Purpose	Some students evaluated the problems based on personal convictions as a criterion. However, they were ***not able to articulate and explain with clarity*** how decisions were made based on personal conviction to select the problem as a goal for this design project. In some cases, justification to choose the problem based on personal conviction were ***shallow***. [4] (refer to Figure 10)
Information	When choosing a problem, most students did not gather adequate information to support their decision-making processes. Their decision-making processes are mainly based on their own assumptions of the problems but may be ***inaccurate*** which further make ***unfair evaluations*** to some extent. [14] (refer to Figure 11)
Concepts	One student clearly displayed ***a lack of depth in thinking*** about the concept related to criteria to evaluate the problems in the decision matrix. This is evident in his /her ***superficial*** evaluations of all the problems. [1] (refer to Figure 10)
Assumptions	As a whole, for students using the decision matrix, the evaluations made with regards to the problems were mainly based on their assumptions that ***may not be accurately justified*** by evidence. [9] (refer Figure 1)
Implications and Consequences	For students using the decision matrix, some of the evaluations were made based on ***unclear*** implications and consequences. [2] (refer to Figure 10)
Inferences	In general, most students did not seek to figure out their assumptions of the problems that lead to their inferences related to the problems. Thus, this led to making inferences based on ***unjustified*** and ***faulty*** assumptions related to the problems that may influence their decision-making processes to choose a problem. [14]

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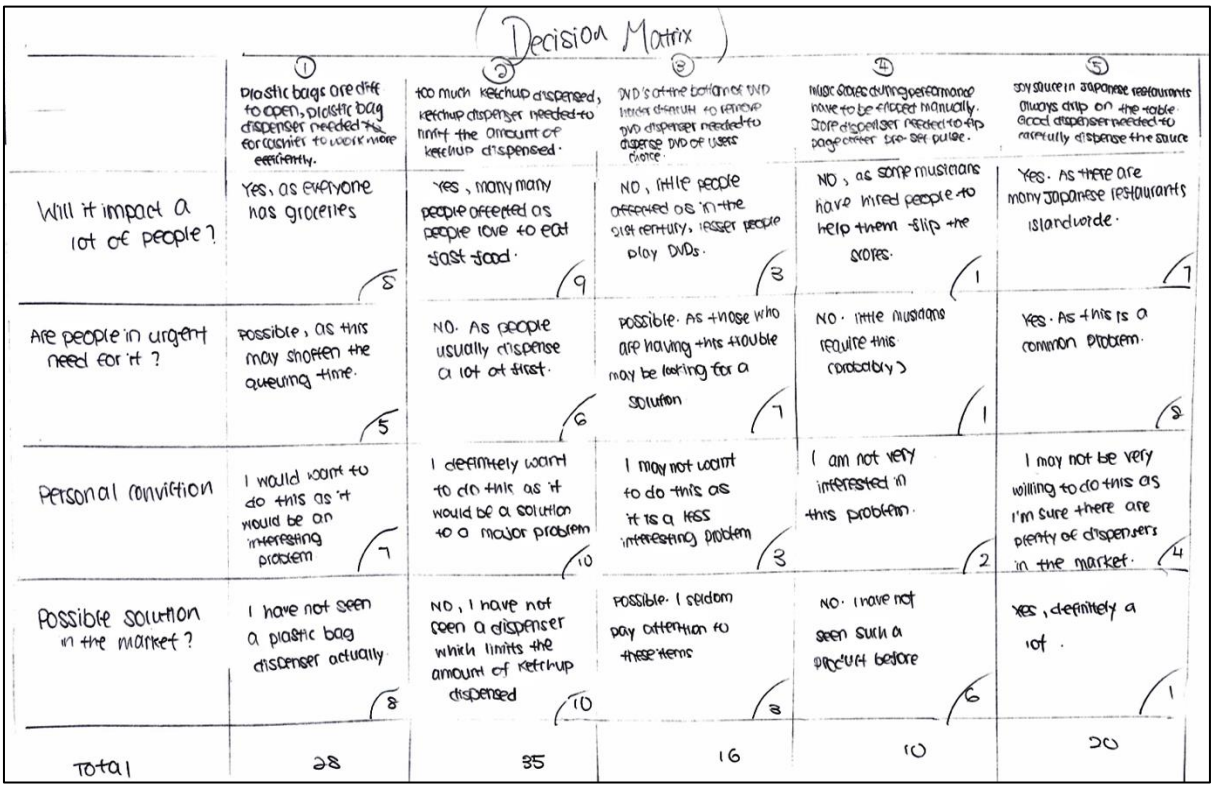

Figure 10. An example of a student's vague evaluations that clearly displayed weak reasoning in elements such as purpose, concepts and implications.

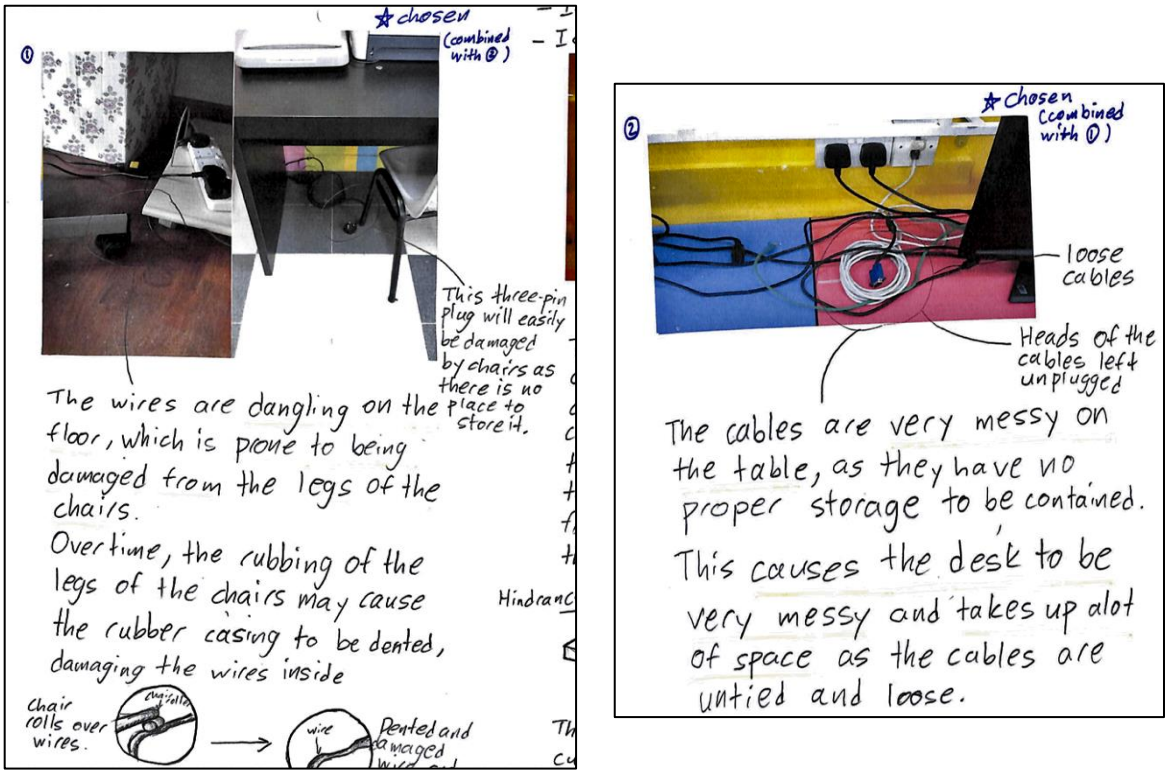

Figure 11. An example of a student who chose the problem based on his own interpretation of the problem through field observation, but his decision was not supported by other forms of data or information.

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5. Discussions

The current study presented an approach to dissect students' critical thinking into the various elements of reasoning and then assessing these elements of reasoning using the intellectual standards that are contextualised for the current study. Although current study is based on Singapore context, the findings may provide the following implications for critical thinking development in D&T design projects with respect to choosing a design problem.

5.1 The Need to Strengthen the Quality in Critical Thinking Process

The collective cases formed based on the analysis of documentations in the design journals in this study provided important insights to understand how students exercise critical thinking when choosing a design problem. From the documentations in the design journals, it is clear that students do go through a process of critical thinking to evaluate the problems so that a decision can be made when choosing a design problem. Such systematic decision-making process can be seen in the form of the decision matrix.

Although students went through a systematic decision-making process, their decisions were often justified based on their assumptions. In decision matrix, students were able to articulate their evaluations of the problem clearly and logically, but these evaluations were mainly based on assumptions that were inaccurate or not justified by sufficient evidence. Thus, the final decision to choose a design problem may not be fully justified. For students who did not use the decision matrix to evaluate their options when choosing a design problem, most seem able to provide reasons to support their choice of problems, but their reasons were mainly based on assumptions made without any evidence to support such assumptions. Thus, the observations in the design journals shown that though students may have gone through the critical thinking process, but that do not equate to achieving the desired quality of the critical thinking process. One of the main reasons is that students do not conduct much research to verify their evaluations of the problems when choosing a problem. Thus, mostly falling back on their own assumptions.

5.2 Suggestions to Strengthen the Quality in Critical Thinking Process

In order to sharpen students' critical thinking to achieve quality reasoning during the process of problem selection, the suggestions in this section may provide educators with useful insights when teaching the problem identification process for D&T design projects.

Firstly, a more systematic process of information or evidence gathering to support decision-making may be necessary. For example, in the use of the decision matrix, the selection criteria for

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choosing a problem may be formed early in the problem identification process. In other words, before students engage into the process of problem exploration, the selection criteria necessary for decision-making when choosing a problem should be formed. In fact, when forming the selection criteria, students should also justify the need for each criterion with support or evidence instead of just resting on their assumptions. Once the selection criteria are formed, students can systematically research on required information or evidence with respect to the selection criteria during the problem exploration process. This will provide the basis for decision-making when choosing a problem. While this process does not mean to restrict students' exploration of problems during the divergent thinking process; but by knowing the selection criteria in advance, this will sharpen students search for information to understand the problem better and in turn form important background knowledge that is necessary to perform quality reasoning during the problem selection process. This in-turn may sharpen critical thinking.

The decision-making process in choosing design problems formed an excellent opportunity for the development of ethical reasoning in the critical thinking process (Sternberg, 2017). In the face of a list of design problems, students are confronted with deciding on which problem should be solved instead of the others. Such decision-making process touch on ethical considerations in reasoning. For example, choosing a design problem that affects the lives of many people as compared to problems that affect individuals; or addressing a need rather than a want; or addressing sustainable issues rather than promoting consumerism and wastage. Perhaps, through this process students may be able to think much deeper how design can contribute to natural environment and mankind, and experience the ethical struggle in design, rather than just considering the commercial aspect of design.

In addition, students should also evaluate the possible problems based on their personal emotions such as conviction and interest in the problem, which may be affected by their values. By going through such a process, students may be more aware of how their own emotions affect decision-making, especially in choosing the types of problems to solve. It should not be discounted that students are usually more motivated in solving problems that they are interested in and have personal conviction. Finally, students can also be taught to choose realistic goals in the form of design problems that can be solved within their means. Thus, when forming selection criteria for choosing problems, it is suggested that students should focus on factors such as ethical, significance, reasonability, relevance, emotions and achievability.

5.3 Infusing the Elements of Reasoning into the Curriculum for Design-Based Learning

Taking D&T in Singapore as an example, the current national syllabus and assessment criteria mainly focus on assessing students' competencies in the design process. Although critical thinking is

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expected to be developed when students go through the design process, how critical thinking can be evaluated is still not well defined. In order to evaluate the quality of critical thinking displayed by students, methods to articulate the standards for quality critical thinking need to be developed.

The current study provides a possibility of an approach to deconstruct reasoning required for a particular stage in the design process. Using critical thinking model by Paul and Elder (2002, 2019), the standards for good reasoning required for a particular stage in the design process can be articulated based on expected student outcomes. Using the set of standards articulated specifically for a particular stage in the design process, it is possible to evaluate the quality of students' critical thinking at every major juncture in the design process.

Based on the expected student outcomes defined in the national syllabus, which will translate into the curriculum of each school, curriculum developers at school level may develop a set of standards that can be applicable to evaluate students' critical thinking in the design projects. On the other hand, curriculum developers at national level may consider the approach presented in this study to develop a set of relevant standards that may be used by schools to evaluate the quality of critical thinking in students during design-based learning.

In the aspect of developing students with skills to achieve good reasoning during the design process, the standards for good reasoning will also be useful to teach students how to reason through the different elements of reasoning. As there are eight elements of reasonings, D&T programmes in school curriculum may need to scaffold learning activities that can develop students with the different elements of reasoning by stages and with different intensity. This is because, it may not be possible for students to internalise all eight elements of reasoning at one go.

6. Limitations of Study

As limitations to this study, current findings are based on evidence from the design journal. However, what goes into the discussion between students-teachers, students-users and students-stakeholders, that may influence students' decision-making are not able to be clarified, although some students did note some of the discussions. In a way, how students derived the selection criteria in the decision matrix are mostly unknown. There may have been formed after certain discussions with teachers, stakeholders, friends. To cover such possibilities, any queries about the documentations in journals were clarified with the teachers as much as possible.

7. Conclusion

The current study aimed to identify and clarify students' critical thinking processes when choosing a design problem by using Singapore D&T as a context. Breaking down students' critical

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thinking into elements of reasoning, the quality of reasoning can be assessed using intellectual standards. From the study, the follow main points may be summarised.

Firstly, the use of decision-making tools does not necessary enable students to achieve quality reasoning. While students may be able to articulate clearly and logically their choice of the problem, but in most cases, their decisions are mainly based on assumptions which may not be well justified. Thus, a more systematic process of information or evidence gathering is necessary.

Secondly, the selection criteria for choosing a problem should be formed early in the problem identification process, before students engage into problem exploration. By doing this, students may be able to know the selection criteria in advance, this will sharpen students search for information to understand the problem better and in turn form important background knowledge that are necessary to perform quality reasoning during the problem selection process.

Thirdly, the process of choosing problems may be a good opportunity to touch on students' ethical and emotional considerations towards the problems. Thus, when forming the selection criteria to choose a problem, it is suggested that students should focus on factors such as ethical, significance, reasonability, relevance, emotions and achievability.

Finally, the current study may provide curriculum developers with some fruits for thoughts on the possibilities to develop relevant assessment standards that may be useful in evaluating and developing quality critical thinking in design-based learning.

8. Acknowledgements

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韓國高中科技教育的變遷

摘要

在南韓，科技教育是全國國定課程的科目之一。然而，高中科技教育仍然面臨了一些挑戰。韓國科技教育社群將克服這些挑戰列為優先事項。本研究的目標是檢視南韓高中科技教育的變遷。為達成此目標，本研究使用了韓國政府的「學校資訊系統」，並分析了忠清南道地區所有學校的課程文件。本研究蒐集並分析了 2018 至 2020 年的數據，用以了解高中科技教育的變遷。研究發現：（一）「科技與家政」科在共同選修科中佔比逐年減少；（二）職業選修科中，與科技教育有關的科目為「工程學入門」和「智慧財產入門」；這些科目大多在高中最後一年的專業課程中教授;高中科技教育在共同選修科中地位下降的趨勢相當明顯。韓國科技教育的專家應著力研究以提升高中科技教育在共同選修科中的佔比。此外，新設立的職業選修科有助於提升大家對高中科技教育的重視。未來的研究可進一步探究其他高中科技教育的傑出實例，並與其他科技教師分享。

關鍵詞：高中、科技教育、工程、課程

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Transition of High School Technology Education in Republic of Korea

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Abstract

Technology Education (TE) has been one of the national curriculum subjects in South Korea. However, TE in high school has faced several challenges. Overcoming these challenges has been a priority to the community of Korean Technology Education. The goal of this study was to examine a transitional status of Korean high school technology education in South Korea. To accomplish the goal, this study utilized the School Information System operated by Korean government and analyzed all school curriculum documents in Chungnam Province. Data from 2018 to 2020 were collected and analyzed for identifying transitional status of high school TE. The findings are as follows: 1) Technology and Home Economics as a general selective subject has been decreased yearly. 2) TE related subjects as a career selective subject are Introductory Engineering and Introductory Intellectual Property. These subjects have been largely implemented in the concentration of the final year of high school. High school TE has had a clear trend of losing the place as a general selective subject. Korean TE professions should pay attention to progressive strategies for increasing high school TE in the perspective of general selective subject. In addition, new career selective subjects can be a good chance to get more attention from others in terms of high school TE. Further studies are needed to develop good cases of high school TE and share with other technology teachers.

Keywords: High School, technology education, Engineering, curriculum

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1. Introduction

On September 4, 1964, Korea's technology education first appeared in the revised high school curriculum. Since then, the curriculum has been revised eight times. From the first curriculum to the fifth curriculum, the subject's title was Technology. In sixth curriculum, Technology and Home Economics are merged. The subject's title, Technology and Home Economics has been used so far. From the first curriculum to the third curriculum, the educational objectives of technology were to emphasize the acquisition of basic knowledge and skills. The fourth and fifth emphasized the technological literacy that could adapt to high industrialized society. From the sixth to the 2015 revised curriculum, developing technology literacy has been emphasized (Lee & Kwak, 2017).

In Republic of Korea, recent big changes in education are the implementation of the 2015 revised national curriculum and the high school credit system. The Ministry of Education (MOE) announced the 2015 revised national curriculum, a new curriculum, to foster creative people who can solve problems by converging knowledge (MOE, 2014). In 2020, the 2015 revised national curriculum is being implemented in all schools. The most concentrated transitions about the 2015 revised national curriculum are students' participation- based instruction and process-based assessment (MOE, 2017a).

In 2017, the MOE announced that high school credit system, which is a curriculum that allows students to select various subjects according to their career. Previously, subjects could not be chosen. Students graduated if they take a class according to the fixed timetable. However, if the credits you have completed reach the standard, students will graduate. It was initially planned to be implemented nationwide in 2022. But in the face of various problems at spot of education, such as the supply and demand of teachers and the development of curriculum, it was decided to implement in 2025(Shin, 2019, Lee & Baek, 2019). The high school credit system organizes and operates elective courses that reflect students' demand, and guarantees students' choice as much as possible (MOE, 2018).

In high school, technology is an elective, not a compulsory subject. Since the sixth curriculum, Technology and Home Economics have been classified as general elective subjects (Lee & Kwak, 2017). In the 2015 revised high school curriculum, technology education subject was classified as a group (Technology and Home Economics/Second Language/Chinese Language). The most noticeable change in the 2015 revised technology curriculum is the creation of "Introductory Engineering" and "Introductory Intellectual Property" in career electives subjects (MOE, 2015a).

Introductory Engineering aims to understand and experience the various engineering worlds through the convergence with the basic principles of various engineering worlds, so students can predict future engineering and design their career (MOE, 2015b). Introductory Intellectual Property

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aims to understand intellectual property and to cultivate creative thinking and attitude that can create new values in real life (MOE, 2015b).

Introductory Engineering and Introductory Intellectual Property have emerged in accordance with the needs of society in environment that technologies and engineering are rapidly emerging and developing. Introductory Engineering is based on the creative engineering design, and Introductory Intellectual Property is centered on the process of solving the invention problem (MOE, 2015b). Students can develop creative thinking skills and problem-solving skills. The two subjects have same value of Technology Education, technology literacy, based on the problem-solving process (Park, 2019).

Ahead of the implementation of the high school credit system, technology education is facing various demands to consider organizing and operating elective subjects in order to structure the high school curriculum (Lee & Baek, 2019, Park et al., 2020, Kwon & Lim, 2020). Therefore, it is necessary to figure out how technology education is currently being operated in the spot of education.

This study looks at the changes in the Technology Education curriculum of South Korean high schools to design curriculum suitable for the transitions. This study will look at the current status of Technology Education in South Korea high schools to be used as basic data.

2. Background

2.1 Types of Korean high school

High schools in Republic of Korea are classified as general high school, autonomous high school, specialized high school, and special purpose high school. General high school provides general education in various fields. Autonomous schools autonomously operate curriculum in accordance with the educational goals of schools. Autonomous high school has autonomous private high school and autonomous public high school. Special purpose high school provide professional education in the fields of science, art, physical education, and occupation. Special purpose high school is divided into science high school, foreign language high school, physical education high school, art high school, and Meister high school. Specialized high schools provide education for students who want to get a job after graduation. Meister high school also has the same target, but education is conducted with the aim of training professionals in more professional fields.

Depending on the type of educational purpose the types of subjects divided into ordinary subjects and specialized subjects.

Table 1

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Types of Korean high school

		Purpose of education	Types of subjects
General high school		General	Ordinary subjects
Autonomous high school	Autonomous private high school	General	Ordinary subjects
	Autonomous public high school	General	Ordinary subjects
. Special purpose high schools	Science high school	General	Specialized subjects Ⅰ
	Foreign language high school	General	Specialized subjects Ⅰ
	Physical education high school	General	Specialized subjects Ⅰ
	Art high school	General	Specialized subjects Ⅰ
	Meister high school	Vocational	Specialized subjects Ⅱ
Specialized high school		Vocational	Specialized subjects Ⅱ

2.2 Types of subjects: Ordinary subjects, specialized subjects

Usually, Ordinary subjects are divided into common and optional subjects. Common subjects are Korean, Mathematics, English, Korean history, Integrated society, and Integrated science (including scientific exploration experiments). All students developed a common subject consisting of what they must learn in high school and all students were required to complete it.

Optional subjects are divided into general elective subjects and career elective subjects. The optional subjects to support customized education based on students' aptitude, career and interest were divided into general elective subjects and career elective subjects. General elective subjects were organized based on the basic understanding of each subject required at the high school level. The career choice subjects consisted of subjects that could be converged between subjects, career guidance, advanced study and real life experience learning.

Specialized subjects are divided into specialized subjectsI operated by special purpose high schools(except for Meister high school), and specialized subjects II operated by Meister and Specialized high school. Specialized subject I is about science, physical education, arts, foreign languages, and international categories. Specialized subject II is divided into specialized common subjects, basic subjects, and practical subjects according to NCS(National Competency Standards). A variety of optional subjects will be opened by developing career-selective subjects so that students can have advanced learning and career exploration experiences according to their career paths. This allows students to choose subjects based on their interests and careers.

Table 2

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Subjects in Korean high school

Field	Subjects (group)	Common subjects	Elective subjects	
			General elective subjects	career elective subjects
Basic	Korean	Korean	Speech and composition, Reading, Language and media, Literature	Practical Korean, Advanced Korean, Classical Reading
	Mathmatics	Mathmatics	Mathematics 1, Mathematics 2, Calculus, Probability and Statistics	Practical mathematics, Geometry, Economic mathematics, Math tasks
	English	English	English conversation, English 1, English reading and writing, English 2	Practical English, English-speaking culture, Career English, English-American literature reading
	Korean History	Korean History		
Exploration	Unified society	Unified society	Korean geography, World geography, World history, East Asian history, Economics, political and legal, Social and cultural, Life and ethics, Ethics and ideas	Travel geography, Exploration of social issues, Classics and ethics
	Integrated science Scientific exploration experiment	Integrated science Scientific exploration experiment	Physics 1, Chemistry 1, Life Science 1, Earth Science 1	Physics 2, Chemistry 2, Life Science 2, Earth Science 2, Science History, Life and Science, Convergence Science
Physical education and Art	Physical education	Physical education	Physical education, Exercise and health	Sports, Exploration of Physical education
	Art	Art	Music, Art, Theater	Playing music, Listening to and criticizing music, Creating art, Appreciating and criticizing art
culture of life	Technology and Home economics		Technology and Home economics, Information	Agricultural Life Sciences, Introductory Engineering, Creative Management, Marine Culture and Technology, Home Science, Introductory Intellectual Property
	Second language		German1, French 1, Spanish 1, Chinese 1, Japanese 1, Russian 1, Arabic 1, Vietnamese 1	German 2, French 2, Spanish 2, Chinese 2, Japanese 2, Russian 2, Arabic 2, Vietnamese 2
	Chinese character		Chinese character 1	Chinese character 2
	Refinement		Philosophy, Logic, Psychology, Pedagogy, Religion, Career and occupation, Health, Environment, Practical economy, Essay writing	

3. Methods

3.1 Data

Among a total of 120 high schools located in Chungnam Province, this study analyzed 82 general high schools, except for specialized high schools aimed at vocational education. 82 schools are studied, as shown in Table 3.

Table 3

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Selection of high school

Types		N	Selection
Special Purpose High School	Science high school	1	✓
	Foreign language high school	1	✓
	Physical education high school	1	✓
	Art high school	2	✓
	Meister high school	4	
Specialized high school		32	
Autonomous private high school		2	✓
General high school		75	✓
Etc.		2	
		120 Schools	82 Schools

3.2 Data Collection

Documents required for analysis were collected using school information website (https://www.schoolinfo.go.kr/). According to the regulation of MOE, all schools in South Korea should announce their basic information like school yearly plan. At this study, we downloaded and analyzed the documents contained curriculum. Figure 1 is main shot of school information website. Table 4 is collected data.

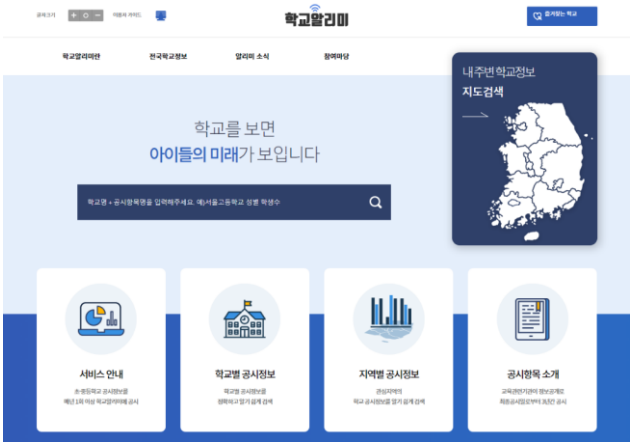

***Figure* 1**. School information website

Table 4
Collected item

Category		Number of item	Item
3. Educational environment	2. Education Plan	2-A	Matters concerning the organization, operation, and evaluation of school curriculum

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3.3 Framework of curriculum planning document's analysis

To analyze the current status of technology education in high schools in Chungnam Province, the curriculum planning documents was analyzed. The researchers gained knowledge of curriculum planning documents in advance and understood the analysis of curriculum planning documents. The items in analysis were confirmed by three technology education experts. The items collected for the survey are as shown in Table 5. Analysis table for the collected items is Figure 2.

Table 5
Collected items

Category	Content of analysis
1. Basic school information	A. Location B. School Name
2. Items about class	A. Status of adoption of elective courses in high school B. Status of operation by grade in elective subjects in high school C. Distribution of class time for elective subjects

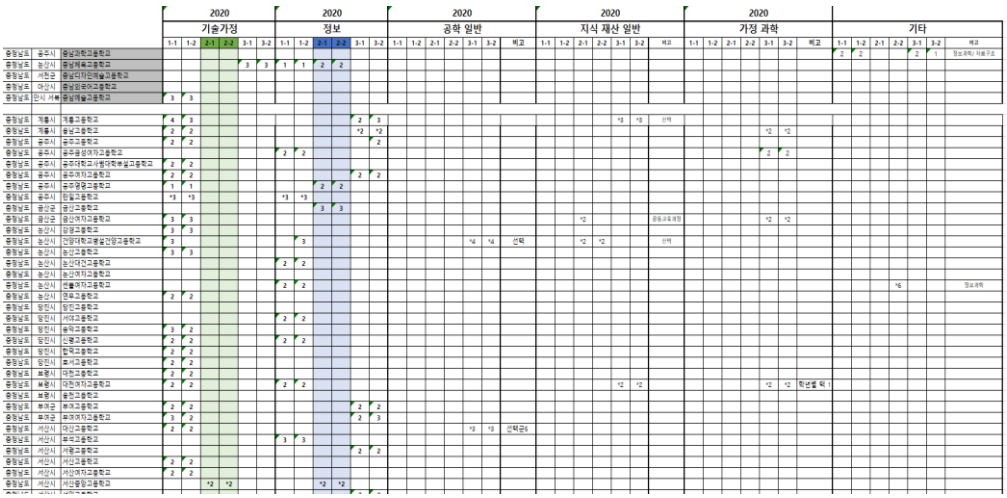

Figure 2. Analysis table

3.4 Limitation of data analysis

Descriptive statistical analysis and average analysis were performed using Excel for statistical analysis of basic data of each school and the number of classes per semester. The analysis excluded schools that were the disclosure of school information. In addition, the analysis of this study was conducted on high schools in Chungnam Province and may have limitations in generalizing the results into situations in other cities and provinces.

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4. Status and Issues of High School Technology Education

4.1 Status of adoption of general elective courses in high school

According to analysis on the selection status of general elective subjects about 82 general high schools in Chungnam Province, Technology and Home Economics are being implemented in 63 schools in 2018, 76.81% out of 82 schools. In 2019, 64 schools, 78.05%. In 2020, 60 schools, 74.04%. Information was conducted in 44 schools, 53.65% out of 82 schools in 2018, 46 schools in 2019, and 50 schools, 60.98% in 2020.

Table 6
Status of adoption of general elective courses in high school

	2018		2019		2020	
	N	%	N	%	N	%
Technology & Home Economics	63	76.81	64	78.05	60	74.07
Information	44	53.65	46	56.1	50	60.98

4.2 Status of operation by grade in general elective subjects in high school

Most of the classes are organized and operated in the first grade in 2018, 2019, and 2020. On the other hand, information classes were the most frequently conducted in the second year of 2018, with 40.91 percent out of 46 schools that implement information. But in the 2019 and 2020, they are evenly operated in the first, second and third grades regardless of the specific grade.

4.3. Distribution of class time for general elective subjects

Comparing the average number of times of Technology and Home Economics and information, there is not much difference in class time. The number of class times of Technology and Home Economics decreased from 2.44 in 2018 to 2.42 in 2020. Information has increased class time from 2.34 in 2018 to 2.4 in 2020. Of the 82 high schools in the humanities, there are more schools that adopt technical families than information, while the number of times in operation is greater than that of technology and families.

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Table 7
Status of Technology and Home Economics operation by grade

	Technology and Home Economics					
	2018		2019		2020	
	N	%	N	%	N	%
10 – 1 semester	3	4.76	3	4.69	4	6.67
10 grade	55	87.3	58	90.62	53	88.33
11 grade	2	3.17	1	1.56	1	1.67
12 grade	1	1.59	-	-	1	1.67
10 grade, 11 - 1 semester	-	-	2	3.13	-	-
10 grade, 11 grade	2	3.17	-	-	1	1.67
	63	100	64	100	60	100

Table 8
Status of Information operation by grade

	Information					
	2018		2019		2020	
	N	%	N	%	N	%
10 – 2 semester	2	4.55	3	6.52	2	4
10 grade	7	15.9	13	28.26	14	28
11 – 1 semester	1	2.27	2	4.35	2	4
11 – 2 semester	1	2.27	-	-	-	-
11 grade	18	40.91	12	26.09	13	26
12 – 1 semester	1	2.27	1	2.17	-	-
12 – 2 semester	-	-	1	2.17	2	4
12 grade	6	13.64	7	15.22	12	24
10 grade 11 – 2 semester	-	-	2	4.35	-	-
10 grade, 12 grade	3	6.82	2	4.35	-	-
10 grade, 11 grade	2	4.55	1	2.17	2	4
11 grade, 12 grade	3	6.82	1	2.17	1	2
	44	100	46	100	50	100

Table 9

Distribution of class time for general elective subjects

	Technology and Home Economics				Information			
	Min	Max	Sum	Avg.	Max	Min	Sum	Avg.
2018	0	5	295	2.44	0	4	232	2.34
2019	0	5	298	2.42	0	8	240	2.4
2020	0	5	273	2.42	0	6	242	2.4

**Hours for each week*

Table 10

Technology and Home Economics distribution of class time

	2018						2019						2020					
Semester / Hr/week	1-1	1-2	2-1	2-2	3-1	3-2	1-1	1-2	2-1	2-2	3-1	3-2	1-1	1-2	2-1	2-2	3-1	3-2
0	23	26	80	80	81	81	21	24	81	81	81	81	25	29	79	80	80	80
1	1	1	0	0	1	1	1	2	0	0	1	1	1	1	1	0	0	0
2	29	34	1	1	0	0	32	37	1	1	0	0	32	34	1	1	0	0
3	24	19	1	1	0	0	23	16	0	0	0	0	19	15	0	0	1	1
4	4	1	0	0	0	0	4	2	0	0	0	0	3	1	0	0	0	0
5	1	1	0	0	0	0	1	1	0	0	0	0	1	1	0	0	0	0
Sum	148	135	5	5	1	1	155	137	2	2	1	1	139	123	3	2	3	3
N	59	56	2	2	1	1	61	58	1	1	1	1	56	52	2	1	1	1
Avg*	2.51	2.41	2.5	2.5	1	1	2.54	2.36	2	2	1	1	2.48	2.37	1.5	2	3	3

Schools that adopt Technology and Home Economics are organized and operated at two hours in most schools in 2018, 2019 and 2020. The total number of times in Technology and Home Economics was 295 in 2018, 298 in 2019, and 273 in 2020. The number of class hours increased by 3 in 2019 compared to 2018 but decreased by 25 in 2020 compared to 2019.

There are largest number of schools operated by organizing two hours of information classes in 2018, 2019, and 2020. The total number of times in information teaching continues to increase to 232 in 2018, 240 in 2019 and 242 in 2020.

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Table 11
Information distribution of class time

Semester / Hr/week	2018						2019						2020					
	1-1	1-2	2-1	2-2	3-1	3-2	1-1	1-2	2-1	2-2	3-1	3-2	1-1	1-2	2-1	2-2	3-1	3-2
0	69	67	59	60	69	69	64	61	64	66	68	69	62	60	64	66	69	64
1	3	4	0	0	0	0	3	5	0	2	0	0	3	3	0	0	1	3
2	8	6	14	14	8	8	10	7	11	8	8	7	9	12	7	7	9	9
3	2	4	7	5	4	5	4	8	5	4	5	6	6	5	8	6	1	4
4	0	1	2	3	1	0	1	1	1	2	1	0	1	1	2	2	0	0
ctc	0	0	0	0	0	0	0	0	8(1)	0	0	0	0	0	0	0	6(1)	6(1)
Sum	25	32	57	55	32	31	39	47	49	38	35	32	43	46	46	40	28	39
N	13	15	23	22	13	13	18	21	18	16	14	13	19	21	17	15	12	17
Avg*	1.92	2.13	2.48	2.5	2.46	2.38	2.17	2.24	2.72	2.38	2.5	2.46	2.26	2.19	2.71	2.67	2.33	2.29

4.4 Status of adoption of career elective courses in high school

Engineering Technology implemented in the 2009 revised curriculum were implemented in 7 schools in 2018 and 7 schools in 2019. Introductory Engineering, which was first implemented in 2019, was implemented in 3 schools in 2019 and was adopted by 12 schools in 2020. Introductory Intellectual Property was adopted by 2 schools in 2019 and by 7 schools in 2020. In the case of Home Science, 8 schools in 2018, 10 schools in 2019, and 14 schools in 2020. Home Science is being implemented in 8 schools in 2018, 10 schools in 2019 and 14 schools in 2020.

Table 12
Status of adoption of career elective courses in high school

	2018		2019		2020	
	N	%	N	%	N	%
Engineering Technology	7	8.54	7	8.54	-	-
Introductory Engineering	-	-	3	3.66	12	14.81
Introductory Intellectual Property	-	-	2	2.44	6	8.64
Home Science	8	9.76	10	12.2	14	17.28

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4.5 Status of operation by grade in career elective subjects in high school

Introductory Engineering is not being implemented in the first grade but in the second and third grades. Engineering Technology was the most frequently implemented in the third grade at 2018, in the second grade at 2019 and in the third grade at 2020. Introductory Intellectual Property was started in 2019. In 2019, it was operated at 100% of the second grade. In 2020, it is being conducted evenly among first, second and third graders. Home Science was conducted in the second and third grades in 2018. In 2019, it was conducted 30% in the second and third grades. In 2020, it was implemented in the first, second and third grades, and in particular, 57.14 percent in the third grade.

Table 13
Status of Engineering Technology, Introductory Engineering operation by grade

	Engineering Technology, Introductory Engineering					
	2018		2019		2020	
	N	%	N	%	N	%
11 – 1 semester	-	-	-	-	1	8.33
11 – 2 semester	1	14.29	-	-	-	-
11 grade	1	14.29	5	50	2	25
12 – 1 semester	1	14.29	1	10	-	-
12 – 2 semester	1	14.29	1	10	1	8.33
12 grade	3	42.86	3	30	7	58.33
11 grade, 12 grade	-	-	-	-	1	8.33
	7	100	10	100	12	100

Table 14
Status of Introductory Intellectual Property operation by grade

	Introductory Intellectual Property					
	2018		2019		2020	
	N	%	N	%	N	%
10 – 1 semester	-	-	-	-	1	16.67
11 – 1 semester	-	-	-	-	1	16.67
11 grade	-	-	2	100	1	16.67
12 grade	-	-	-	-	2	33.33
11 grade, 12 grade	-	-	-	-	1	16.67
	-	-	2	100	6	100

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Table 15
Status of Home Science operation by grade

	Home Science					
	2018		2019		2020	
	N	%	N	%	N	%
1 grade	-	-	1	10	1	7.14
11 -1 semester	1	12.5	-	-	-	-
11 – 2 semester	2	25	1	10	1	7.14
11 grade	2	25	3	30	3	37.5
12 – 1 semester	1	12.5	1	10	-	-
12 grade	2	25	3	30	8	57.14
11 grade, 12 grade	-	-	1	10	1	7.14
	8	100	10	100	14	100

4.6 Distribution of class time for career elective subjects

Engineering Technology and Introductory Engineering are increasing the total number of class time counts, and the average of class time has also increased from 3.08 in 2018 to 3.18 in 2020. Introductory Intellectual Property is increasing the total number of class times, and the average number of times decreased from 4 in 2019 to 3.18 in 2020. The total number of times in Home Science is increasing, but the average time value has decreased from 3.71 in 2018 to 2.58 in 2020.

Table 16
Distribution of class time for career elective subjects

	Engineering Technology, Introductory Engineering				Introductory Intellectual Property				Home Science			
	Min	Max	Sum	Avg.	Min	Max	Sum	Avg.	Min	Max	Sum	Avg.
2018	0	5	40	3.08	-	-	-	-	0	5	52	3.71
2019	0	4	42	2.8	0	4	12	4	0	4	63	3.15
2020	0	4	89	3.18	0	4	34	3.18	0	4	85	2.58

**Hours for each week*

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5. Conclusion & Discussion

Recent technology education in republic of Korea faced into many transitions. New career elective subjects, Introductory Engineering and Introductory Intellectual Property are emerged by demand of society. With the implementation of the high school credit system that students can choose and take classes according to their careers, various curricula are needed. Overcoming these challenges, this study examined a transitional status of Korean high school Technology Education in South Korea.

The results of the analysis on Technology and Home Economics and information, which are career elective subjects, are as follows.

The number of schools choosing Technology and Home Economics is decreasing. In the other hand, the number of schools choosing information is increasing. Technology and Home Economics are often organized and operated in the first semester of the first year and the second semester of the first year, that is, the first year. Information is organized and operated evenly in the first, second and third grades, rather than in specific grades. There are many schools that have two hours Technology and Home Economics. When comparing the average time, the average time of Technology and Home Economics is higher than that of Information. But the average time is not much different.

The results of studies in career elective subjects such as Introductory Engineering, Introductory Intellectual Property and Home Science are as follows.

The proportion of career elective subjects is the highest in the order of Home Science, Introductory Engineering, and Introductory Intellectual Property. In 2020, only 17.28 percent, 14.81 percent, and 8.64 percent of all humanities high schools adopted Home Science, Engineering, and Intellectual property. But since its inception, more and more schools have chosen little by little.

This study would like to make recommendations based on the results of this study.

First, the general elective courses of high school are currently operated as Technology and Home Economics that combine into one. It is necessary to study whether technology is being operated according to the nature and characteristics of technology teaching at school.

Second, the number of schools to choose from has been increasing since the general subjects of engineering and intellectual property, which are career electives for technical departments, were implemented in 2019. It is understood that this was due to the demand of students who wanted to enter the engineering department. It is necessary to open more diverse career electives in technology subjects so that students can develop careers in engineering.

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發展網路互動聊天機器人之程式設計教材

摘要

本研究旨在透過將過往研究所開發的教材發展為可於網上應用的形式，以改進一種可藉由程序設計互動內容的聊天機器人教材。新開發的教材可實現與聊天機器人在網上的互動。在此學習模式中，學生進行問題制訂，並嘗試以科技解決該問題。學生根據用戶反饋反覆評估和修正，並在最後評估學習任務成效。教材設計以程序設計為基礎，讓學生從過往研究中了解資訊系統機制與特點。由學生所創造的聊天機器人可在網路上被使用，因此學生可收到校外用戶反饋，並利用數據來進行程式除錯。系統以 JavaScript 架設，並以 Vue.js 做為 JavaScript 架構。所開發教材包括聊天機器人的作業系統、專屬程式編輯器、數據管理系統以及上傳系統。資料庫運用雲端後端服務平台 (BaaS) 技術，設計上能夠儲存和分享媒體、使用者記錄以及評估結果。聊天機器人系統基於學生所創建的程式，以聊天機器人的形式使用文字與圖片回應用戶輸入的內容。系統亦具備關鍵字搜索和使用狀況評估的功能。當用戶搜索學生設定的關鍵字時，聊天機器人會給予回應。學生可分析用戶的搜索紀錄和易用性，並修改或改善聊天程式以及搜索詞設定。我們計劃在日本一所國中的科技課運用所開發的教材來驗證其有效性和教學成效。

關鍵詞：中學科技教育、資訊系統、聊天機器人、資訊教育、教材開發

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Development of interactive content programming materials with web-enabled chatbots

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Abstract

This study aims to improve the teaching materials of a chatbot that can program interactive contents using the network, by developing the teaching materials from previous studies into a form that can be deployed on the Web. The developed teaching materials enable interactive interactions with chatbots on the Web. In the learning model, students set a problem and try to solve it with technology. Students repeat the evaluation and correction based on the feedback from users. Finally, they evaluate the learning task. The design of the teaching materials is based on the programming content that allows students to learn about the mechanisms and characteristics of information systems from previous studies. The chatbots created by students are made available on the Web. This makes it possible to receive feedback from users outside the school on the programs they have created, analyze the data, and utilize the data to debug the programs. The system is developed in JavaScript, using Vue.js as a JavaScript framework. The development materials consist of a chatbot operation system, a dedicated program editor, a data management system and upload system. The database uses a cloud-hosted BaaS (Backend as a Service). The database was designed to store and share media and user usage logs and evaluation results. The chatbot system is based on a student-created program that replies to user input with text and images in chatbot form. The system also has a keyword search function and a usage evaluation function. The chatbot responds when the keyword set by the student is searched. The student can analyze the user's search history and usability, and modify or improve the chat program and the search term settings. We are planning to implement the developed teaching materials in a Japanese junior high school technology class to verify their validity and educational effectiveness.

Keywords: Secondary School Technology Education, Information System, Chatbot, Information Education, Educational Material Development

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1. Introduction

Due to the development of information technology, all kinds of things have been converted into data and can be collected via networks. By analyzing and utilizing the accumulated big data, we can receive various services in our lives. AI technology has also spread rapidly and is used to analyze such big data and provide new services. In information technology education in schools, it is important to evaluate new technologies objectively, and to learn and think about the systems from the perspective of developers and users through experience (Furukawa, 2017).

In the Japanese School Guideline for the Course of Study in 2017, the creation of Q&A quizzes and the reproduction of simple chat rooms were shown as examples of problem solving by programming interactive contents using networks. The "interactive content programming using networks" is a new content in the revised Courses of Study, and various teaching and learning materials are being developed and studied in Japan (Ministry of Education, 2017).

Chatbots are an example of the use of such interactive information technology. Chatbots, a combination of the words "chat" and "bot," are "automatic conversation programs" that utilize artificial intelligence, and have a history of over 50 years (Weizenbaum, 1976). Currently, AI technology is also being used, and its introduction is being promoted mainly in corporate customer service. In education, chatbots have been used as learning assistants (Mendoza et. al., 2020). Chatbots are also being used to assist students in learning programming (Benotti et al., 2014). However, there are no examples of chatbots being used as programming tools.

In Japan, Zaima et al. applied artificial intelligence technology to the interactive content programming in junior high school technology department (Zaima et al., 2020). They selected a chatbot as a subject for problem solving by programming interactive contents using the network. The chatbot is programmed by connecting command-type blocks. The recognition of input words is done by Watson machine learning, which is provided by IBM, and the robot learns the correctness of the answer and the correctness of the response by registering a dictionary with machine learning to deal with fluctuations in expression. They performed classroom practices using the developed materials. The results of the survey show that students' interest in programming is increasing and the number of students who recognize the usefulness of artificial intelligence and the need to learn about it is increasing. The practice deals with the use of artificial intelligence and its relation to life and society, but there are few opportunities to understand and experience the inner workings of machine learning in depth.

Kinoshita et al. developed a teaching material that allows students to learn about the mechanisms and characteristics of information systems experientially (Kinoshita et al.,2019). Using a POS system

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used in society as the subject matter, the students experience the information system from the standpoint of both the store and the customer, and the user and the user, and collect and analyze the data of the customers in the system. This is a teaching material that allows students to experience and learn how big data can be used for management strategies in stores. As a result of practical experience, it was confirmed that this is a teaching material that enables students to experience the system from both the customer and the store side and to learn about information systems in society. In addition, it is necessary to experience the system from both the user and the provider's point of view in order to deepen the understanding of the information system. As a challenge, they argue that there is a lack of consideration and development of other information systems, and that there is a need for improvement in order to accommodate interactive content programming.

Suzuki et al. developed a simulated POS system teaching material with a new recommendation system programming function added to the simulated POS system teaching material developed by Kinoshita et al(Suzuki et al.,2020). That allows for experiential learning about the structure and features of information systems. The teaching materials have the ability to analyze the data that the previous developmental materials have. The recommendation system found on product review sites has a built-in programming editor that allows students to program the recommendation function. As a result of the practice, students were able to think about programming from data analysis and understand the concept of recommendation systems. This teaching material enables students to think about the use of information systems.

Suzuki et al. developed and put into practice a programming teaching material for database-based information system programming, which utilizes chatbots to allow students to program information systems using a network (Suzuki et al., 2020). This teaching material is specialized for the school network. However, it can be able to use in a wide range of ways, for example, by developing contents on the Internet, which can be evaluated by people outside the school.

Based on the considerations in the previous studies, we believe that experiential learning about the mechanisms of black boxed systems in information systems will lead to an understanding of the systems. In learning about information systems, dealing with systems from the perspectives of both users and manufacturers and users and users will deepen the understanding of information systems. In addition, in learning interactive content programming, we believe that using chatbot as the subject matter, students can learn about artificial intelligence and AI technology, which has become more and more familiar in recent years in society and in our lives, by actually using the technology of artificial intelligence or by using the technology of artificial intelligence in the process of learning. It is thought that it is easy to incorporate into learning activities, such as learning technology through experiencing the processes performed. In setting up a chatbot as an openly used system, we believe

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that the system can be used not only by students, but also by other users as a teaching material for further development. By having the chatbot evaluated by other students and having a third party outside the school use the chatbot, we can include in the process of creating the chatbot the evaluation and collection of usage data from the target audience and people outside the school. This would increase the amount of data collected from users and the objectivity of the data by adding a perspective other than that of the students to the data for analysis and would increase the awareness of the actual users in designing the chatbot. In addition, it will be possible to use the created chatbot in actual situations, which will make it possible to develop the demand for problem solving using chatbots more widely.

Therefore, the purpose of this study was to develop the teaching materials of Suzuki et al. and improve the teaching materials of chatbots that can program interactive contents on the Web.

2. Method

In the development of the teaching materials, the use of chatbots in previous studies is made possible on the Web. The feature of the developed teaching material is that it is a web application, so the operating environment does not depend on the OS, and it can be used by students and other people outside the school computer room. This enables not only mutual use of the teaching materials among students, but also the collection of usage history and the developmental use of the teaching materials through the use by more people. The teaching materials developed by Suzuki et al. were developed by HSP. The registration information and usage history of chatting bots were managed by a database. SQLite was used as the database. The teaching materials were organized as a set of folders and placed in a shared folder in the computer room so that students could access them from computers connected to the shared network in the classroom.

In our developmental materials, the data and databases sent and received are managed on a cloud server. This allows the programs created by students to be used and data collected from outside the school.

The system is developed using JavaScript, with Vue.js as the JavaScript framework. For database management, we used Firebase provided by Google to ease the development of the back end, such as user authentication and data management. In addition, we have developed a desktop application that can run on a cross-platform environment. We developed each function of the teaching materials as components in Vue.js. Vue.js makes maintenance easier by adopting the MVVM (Model-View-ViewModel) model for the software architecture. In addition, we designed it to reduce data exchange with the server as much as possible.

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For the database, we used a cloud-hosted BaaS (Backend as a Service) to simplify the development of a server for back-end user information and database management, and to store and share media, user usage logs, and evaluation results. It is a back-end service in the cloud for mobile and web applications. You can develop backend functions without the need to manage and operate your own servers. Firebase is a cloud-hosted BaaS (Backend as a Service) provided by Google. We adopted Firebase as our backend service because of its wide range of free services and because we expected to need to manage databases, save files and folders, and set up authentication, etc. Currently, we use Cloud Firestore for data management and Storage for media file storage within Firebase. Firebase's Cloud Firestore is a NoSQL document-oriented database. In Cloud Firestore, all data are stored as key-value pairs. A collection of documents is called a collection. A document can be queried according to the data in it. In the web page of the development materials, you can see the page for each group of students, but the management of the data in the backend in Firebase is done by associating each group's data with a document which is saved, and the same kind of data is managed and operated in the same collection, so that the same kind of data is stored in the database. Firebase Storage is used to store media that is called at chatbot execution time. The free range allows for storage of up to 5 GB of data.

The structure of the development materials is shown in Figure 1. The required Firebase documents are accessed from each web application page. In development, we used encoding.js for character encoding conversion, vue2-ace-editor for text editor integration, and vue-chartjs and Chart.js for graph display as JavaScript libraries.

The model for student learning is that students identify technology-related problems in their lives and society, set challenges to be solved, and solve them by using the way they see and think about technology. Students design and produce a solution to the problem, evaluate and modify the process, and aim to solve the problem with technology. Problem-based learning here can be related to frameworks in STEM Education (Kelley et al., 2016). It has elements of both knowledge and technology learning about programming and information systems, and engineering design that addresses problem solving in a situated learning approach. It also includes elements of design analysis and scientific investigation in student activities. The teaching materials developed by Suzuki et al. are to learn about information processing and flow in chatbots, and to generate ideas from the problem to be solved. Through the design, production, mutual evaluation, improvement, and optimization of the program and data, each group designs, produces, improves, and considers how to optimize the use of the program and data, and considers the learning and application of information systems and AI technology using chatbots as a concrete example.

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In the design of the class design, in the conventional teaching materials, the environment for using the teaching materials was a common network of PCs with access to the same files and folders of the teaching materials. Therefore, the process of mutual use of programs created by students in a class to collect data has been integrated into the learning activities. However, if the target users are limited to students in the school, they can only use chatbots as users of chatbots, which are used in daily life and in society, and assume the number of unspecified users. In this study, we will collect data on the evaluation and use of chatbots by the third parties outside of the school by asking them to use the program we developed in addition to the user evaluation of the previous study. Allow activities to be integrated into the production process. This would increase the amount of data collected from users and add objectivity to the data for analysis by adding a perspective other than that of the student, and increase the actual user's awareness in the design process. In addition, it will be possible to use the created chatbot in actual situations, which will make it possible to expand the demand for problem solving with chatbots more widely than ever before.

3. Development of Teaching Materials

The chatbot material we have developed is organized as a web home page. The interior of the homepage consists of four pages: an operation system, a program editor, a database management system, and an upload system (Fig. 2). All the data displayed on the pages are retrieved from the Firebase server and displayed. Each page asks the user to select a group to which he or she belongs, and by the selection of the group, the system writes and reads the data of each group from the database by internal processing.

In the development materials, the chatbots themselves can be used in the operation page. In the development materials, the chatbots themselves can be used in the operation page, and students can create programs to run the chatbots in the program editor page. At the same time, since students need to create a database for keyword search in advance, they register keywords for search and answers to be displayed on the database management system page. Finally, upload the created program and media files such as images to be displayed to the cloud server from the upload page, and the chatbot can be used from the operation page.

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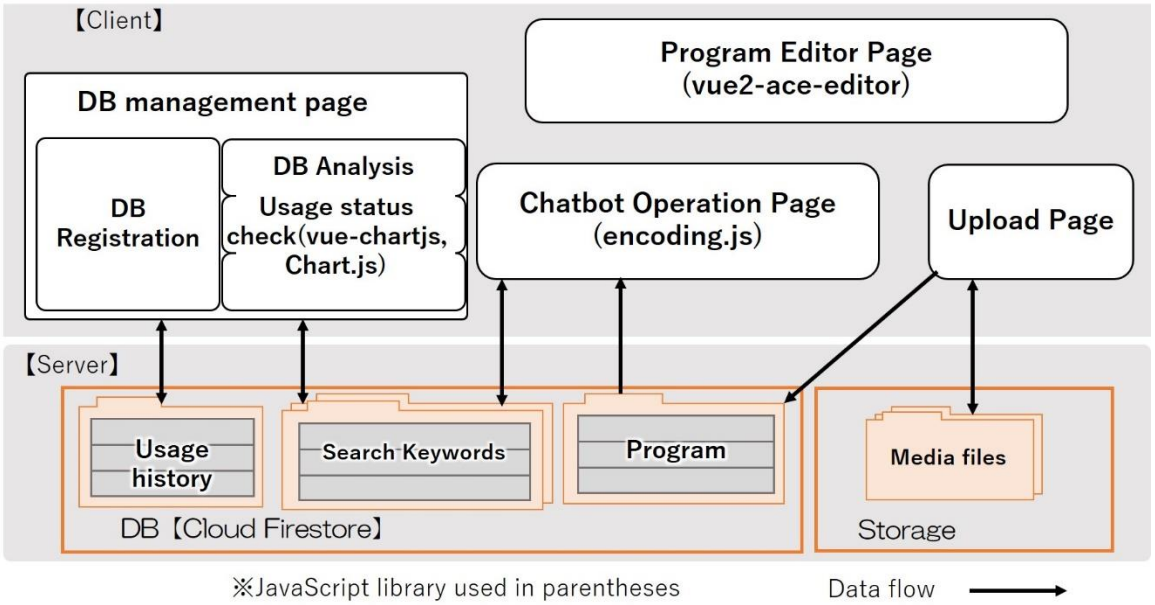

Figure 1. System structure of development materials

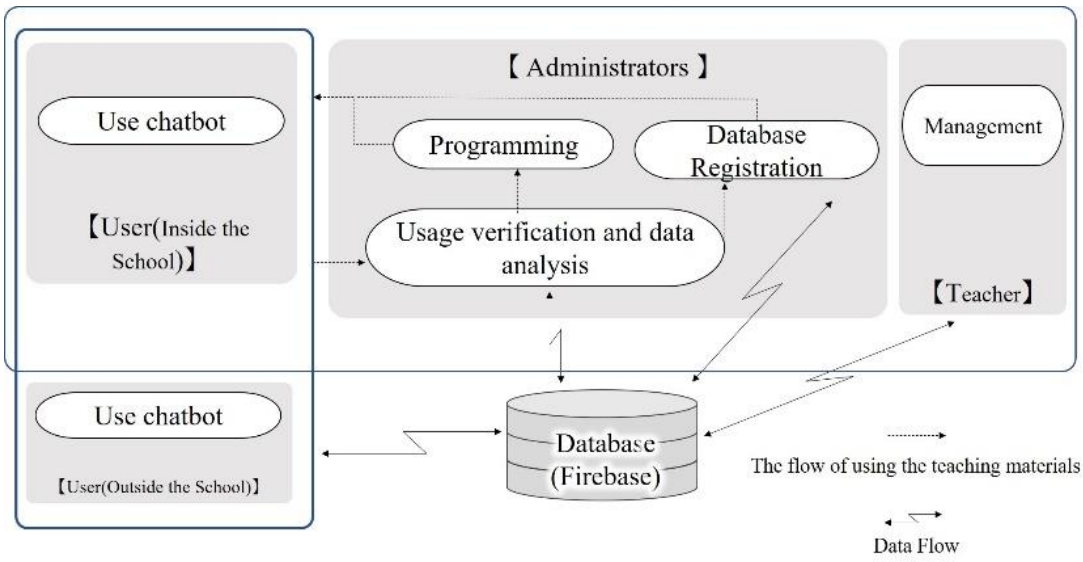

Figure 2. System structure of development materials

By entering the page of the operation system, when the user enters the page of the selected group, the program set by the group is read and the chatbot communication is started. The chat displays alternately the contents of the bot and the user's input (Fig. 3). The user's first input is a specification that recognizes the user's name. The user types the contents of the input in the text box at the bottom of the screen and presses a button to send a message. The bot replies to the input content based on the chatbot program configured for the message. The content of the chat is basically a branching type of

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chatbot communication with conditional branching by numerical choices. The chat also has a database search function. If a word exists that matches a pre-registered keyword in response to a text input, the bot presents the answer of the hit content (Fig. 4). In addition to the text, the bot can display images, music, and videos as explanatory media on the screen, and can also display URL links. At the end of the chat, when the chatbot's closing program command is loaded, a modal window is displayed to review the chat used. The review consists of a point-of-view evaluation and free description based on Suzuki et al.'s teaching materials, and consists of a three-step optional evaluation of "usefulness," "expression," and "usability," and a two-step optional evaluation of "presence or absence of defects (bugs) in operation. to make sure. Records of reviews and chats used are recorded in the database as logs.

The developed teaching materials are run by a dedicated program. The program editor is an editor for writing the dedicated program (Fig. 5). The chatbot program follows the system of the teaching materials in our previous study to be compatible with the teaching materials developed by Suzuki et al. The program was written in Japanese, and the commands were automatically entered into the editor by clicking on the command button after setting the parameters to reduce typing errors by students. The instructions of the program are in the form of instruction tags, like HTML tags, with various instruction commands and text displayed in the chat room (Fig. 6). Chatbot communication transitions from one scenario to another with the scenario instruction tags. The commands in the scenario instructions are executed in sequence. In the scenario, conditional branching by the user's numerical input enables choice type chat communication. In addition, it is possible to jump to another scenario or to repeat the same scenario. The list of instructions of the program is shown in Table 1. The instruction tag sets the parameters and encloses various instructions above and below. Instruction commands are used by inserting them into the instruction tag. Commands for media display of image, music, and video, and databases search are arranged. The program can be saved in a text file format.

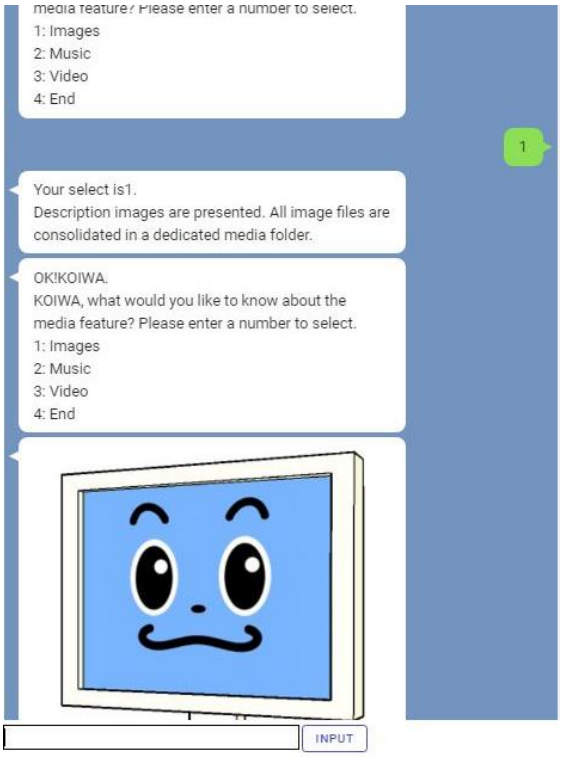

Figure 3. Chat Run Screen

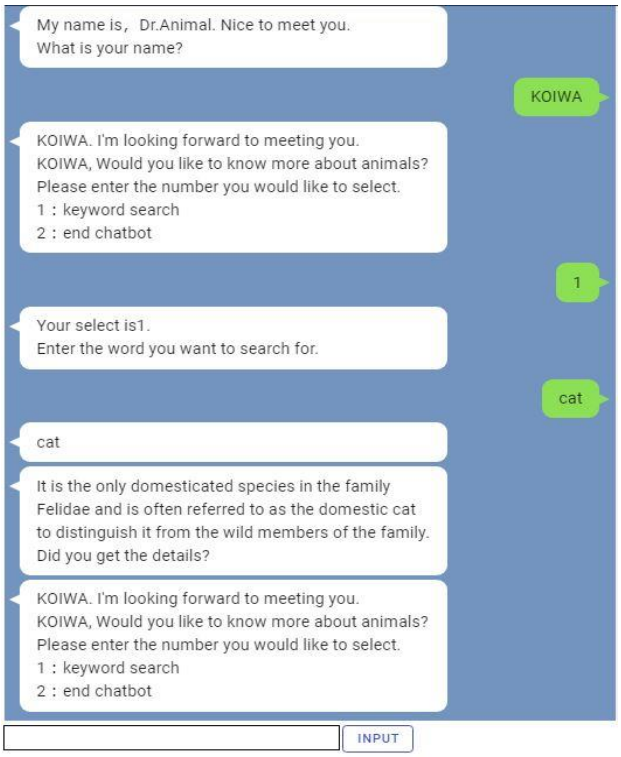

Figure 4. Keyword Search Screen

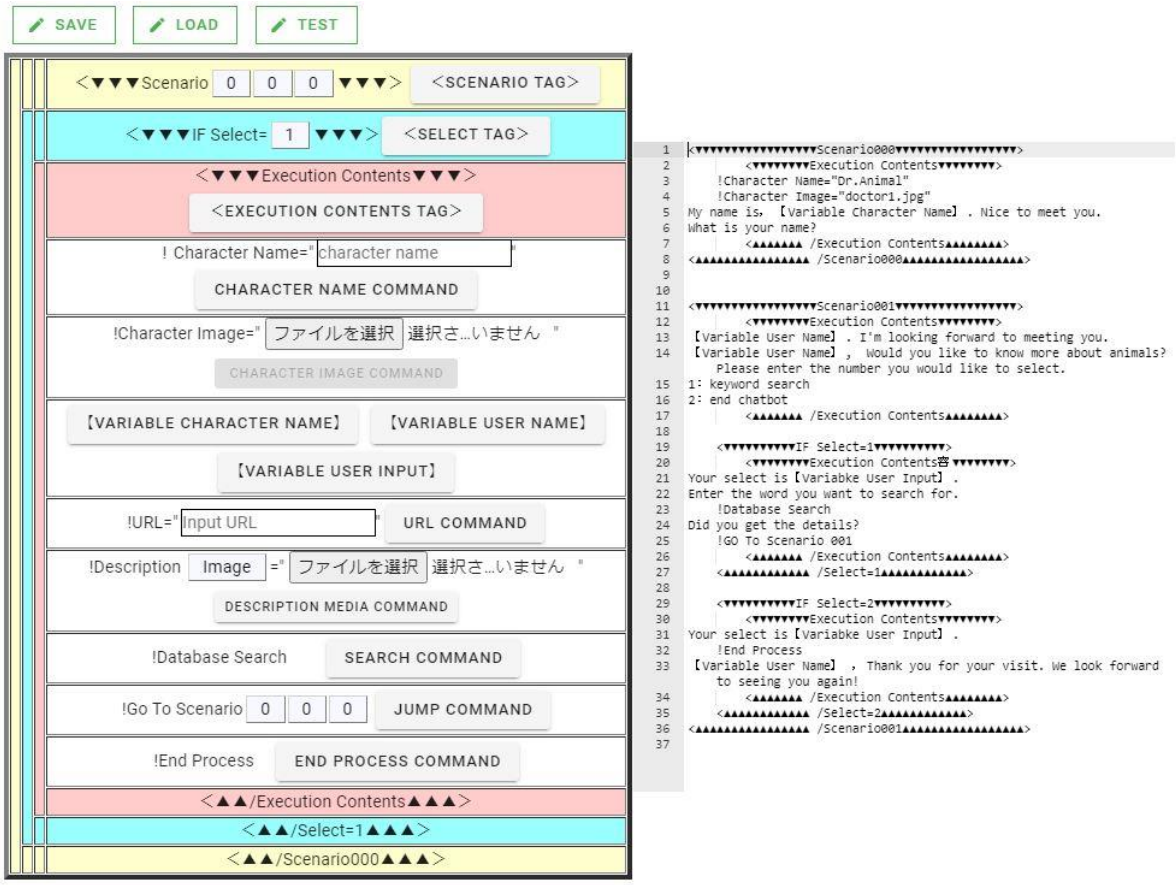

Figure 5. Text Editor

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        <▼▼▼▼▼▼▼▼Execution Contents▼▼▼▼▼▼▼▼>
    !Character Name="Dr.Animal"
    !Character Image="doctor1.jpg"
My name is, 【Variable Character Name】. Nice to meet you.
What is your name?
        <▲▲▲▲▲▲▲▲ /Execution Contents▲▲▲▲▲▲▲▲>
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【Variable User Name】. I'm looking forward to meeting you.
【Variable User Name】,  Would you like to know more about animals? Please enter the number you would like to select.
1：keyword search
2：end chatbot
        <▲▲▲▲▲▲▲▲ /Execution Contents▲▲▲▲▲▲▲▲>

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Your select is【Variable User Input】.
Enter the word you want to search for.
    !Database Search
Did you get the details?
    !Go To Scenario001
        <▲▲▲▲▲▲▲▲ /Execution Contents▲▲▲▲▲▲▲▲>
    <▲▲▲▲▲▲▲▲▲▲▲▲▲▲ /Select=1▲▲▲▲▲▲▲▲▲▲▲▲▲▲>

    <▼▼▼▼▼▼▼▼▼▼IF Select=2▼▼▼▼▼▼▼▼▼▼>
        <▼▼▼▼▼▼▼▼Execution Contents▼▼▼▼▼▼▼▼>
Your select is【Variable User Input】.
    !End Process
【Variable User Name】, Thank you for your visit. We look forward to seeing you again!
        <▲▲▲▲▲▲▲▲ /Execution Contents▲▲▲▲▲▲▲▲>
    <▲▲▲▲▲▲▲▲▲▲▲▲▲▲ /Select=2▲▲▲▲▲▲▲▲▲▲▲▲▲▲>
<▲▲▲▲▲▲▲▲▲▲▲▲▲▲▲▲▲▲▲ /Scenario001▲▲▲▲▲▲▲▲▲▲▲▲▲▲▲▲▲▲▲>
```

Figure 6. Sample Program

The Table 1

List of program instructions (some notations are abbreviated)

Instruction name	Instruction Format	The contents of the instruction
Scenario Instructions	<▼▼Scenario Number▼▼> <▲▲/ Scenario Number▲▲>	What is sandwiched between the lines is treated as a single scenario
Selection Instructions	<▼▼IF Select=Number▼▼> <▲▲/ Select=Number▲▲>	If the user input matches the condition in the second line, the content between the second and third lines is processed as a conditional branch destination
Execution Content Instructions	<▼▼Execution Contents▼▼> <▲▲/Execution Contents▲▲>	What is sandwiched between the lines is processed as the execution content
Character Name Instruction	!Character Name="Character Name"	Can be programmed with character names
Character Images	!Character Image="File Name"	Can be programmed with character images
Variables	【Variable Character Name】 【Variable User Name】 【Variable User Input】	The character specified in the character name instruction, the user's name, and the user's input are presented as substitutions
URL Instruction	<URL>URL</URL>	When you click on a drawing box with an execution content instruction that contains a URL instruction, you can browse the web with URL information between tags
Description Media Instructions	! Description Image="File Name" ! Description Music="File Name" ! Description Mouvie="File Name"	You can program images, music and video files to be displayed in a separate window as description media
Search Instructions	!Database Search	Ask the user to enter a search term, search for keywords, and if there is a search term, the answer will be the content of the response
Jump instruction	!Go To Scenario Number	Transition to the specified number of scenario instructions to be processed

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End Processing Instructions	！End Process	Ask the user for a review and terminate the chatbot operation after processing the rest of the execution instructions after the review is complete

program can be saved as a text file, and the program can be continued by reading the text file.

The database management system consists of two functions: creation of answer sentences for keyword search, and usage check function for viewing the database records. In the answer sentence creation function, when the command of database search is called from chatbot, the data to be retrieved can be created (Fig. 7). The data consists of the keywords to be searched and the answer text. When a user inputs a keyword in a chatbot, if the keyword contains that string, the answer for that keyword is processed as the answer of the bot. The student can register more than one keyword for one answer sentence to respond to fluctuations in the user's input, so the student can set multiple keywords to respond to fluctuations in the user's input. We believe that this enables students to experience how the handling of input fluctuations is done in AI technology that recognizes input contents, including chatbots, which are actually in use.

In the usage review function, we can check three things: user chatbot reviews, chat conversation records, and user keyword search records. For user reviews, we can refer to the distribution of points, averages, and comments of the last review record sent by the users when they used the chat room (Fig. 8). The chat interaction record provides a log of the interaction between users and bots during the use of the chatbot. The record of the keyword search allows users to divide the strings entered by the users in the database search into those that are relevant and those that are not in the answer sentence generation function, and display them in a ranking format. The upload system is a page to upload the chatbot program and various media created by students to Firebase's Storage. By uploading these files on this page, each group can operate the chatbot and display the various media on their chatbot operation page.

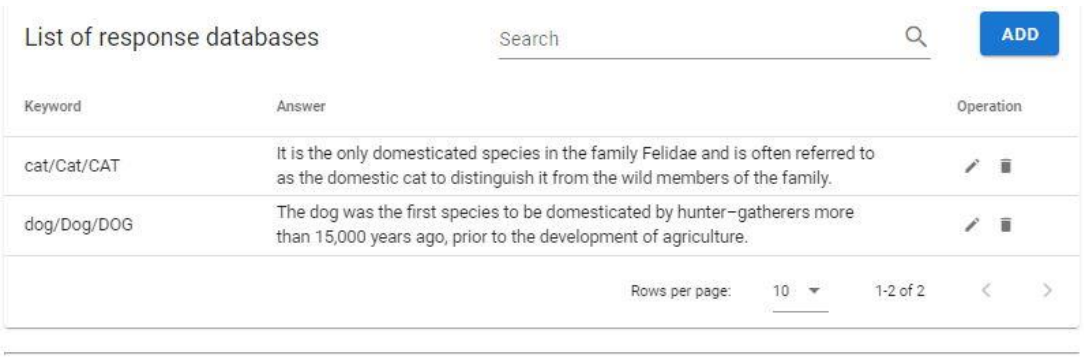

Figure 7. Response writing system

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Figure 8. Review confirmation screen

Each data in Firebase is managed with a unique ID, and a snapshot of the data is taken from the se rver when the front end uses the chat or writes to the database, so that the same data can be used and edited at the same time. We confirmed that multiple users can communicate by chatbot and edit and write to the database at the same time.

4. Results and Discussions

We received an evaluation of our developed teaching materials from a junior high school technology teacher. The developed materials were evaluated for their appropriateness in interactive content programming classes where the materials were used. 11 teachers responded to the evaluation.

The survey was conducted using a 5-point scale (1: disagree~5: I agree).1, 2 and 3 being negative and 4 and 5 being positive. Eleven technology teachers responded affirmatively to the question about the practicability of the technology course. The ability to receive external reviews, which is a feature of the developed teaching materials, was also evaluated positively by 10 teachers. 3 of the 11 respondents had used both the developed materials and the materials developed in the Suzuki's previous study. The teachers evaluated the operability of the developed teaching materials as equal to that of the teaching materials developed in the previous study by three of them. With the developed materials, the chatbot can be used not only in school but also outside of school. This makes it possible

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to collect usage history and reviews not only from students, but also from their families and other people who have access to the web application.

As an example of a class using this material, we propose a simple learning scenario for learners as well as a model for learning. The learning process using the developed teaching materials is based on (2) Problem solving by programming interactive contents using networks, which is a content item (D) Information technology in the Japanese Junior High School Technology Course of Study. The learning model shown in Fig. 9 was set up to correspond to the design process. The students themselves set the problems they want to solve by using the subject chatbot. Next, they think about the design for creating chatbot contents and program them. By having the students use the chatbots they have created, they collect evaluations and usage records from the users, and analyze the data to evaluate and modify the chatbot programs. For example, this could be used to introduce the junior

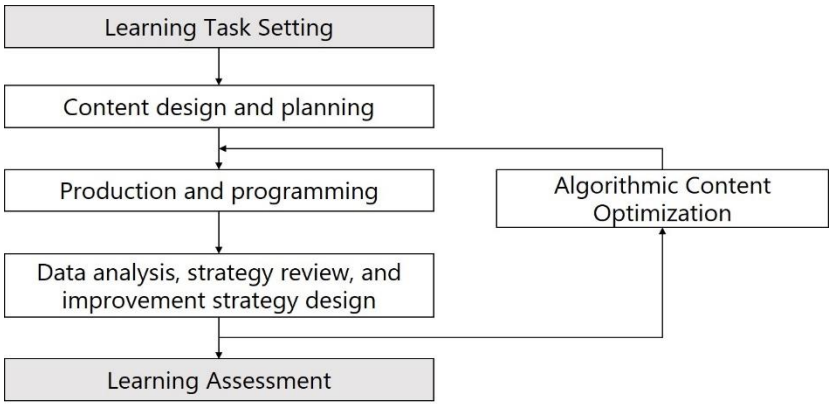

Figure 9. Models of Student Learning

high school to elementary school students before they enter the school, to introduce the school to people in the community, or to let more people know about the SDGs. By repeatedly implementing, debugging, and modifying the chatbots, the students aim to solve the problems they have set. In the process of implementation and debugging, students can also receive evaluations from users outside the school. We believe that this will allow students to think more realistically about the actual use of the content and improve it. Finally, students will be evaluated on the results of their work and the process of solving the problem.

We are planning to implement the developed teaching materials in a junior high school technology class to verify their validity and educational effects.

In our previous study, we managed the media files in a shared folder in the school, so we did not pay special attention to the size of the files. In this study, we had to limit the amount of data that can be stored in the server when we use Firebase for free. We would like to examine, together with the class design, whether it is possible to add specifications for the media used for chatting that students can be aware of, such as the size of the media.

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