EDUCATIONAL RESOURCES TO IMPROVE JAPANESE HIGH SCHOOL TEACHERS' FACILITATION ABILITIES IN PROBLEM IDENTIFICATION AND IDEATION ACTIVITIES

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ABSTRACT
This study aims to clarify the necessary interventions for supplementing teachers' knowledge and skills related to the design process to facilitate the design-based activities in the SDGs Challenge Project. Using a qualitative approach and the SDGs Challenge Project as a case study, this study analysed teachers' feedback before the project started and post-lesson surveys to determine the difficulties teachers have faced in facilitating the design process in 2021 and 2022. The findings showed that teachers have difficulties understanding design thinking, inadequate facilitation skills, limited content knowledge, and unfamiliarity with the worksheets provided. The educational resources for teachers to guide the design process in this project are necessary. The new educational resource should offer knowledge and the methodology of the design process. In addition, resources on pedagogical strategies to facilitate the design thinking is required. Exemplars of student outcomes for each design task and clear explanations of the purpose of each task is also necessary as a resource.

Keywords: Design process, design education, educational resources, problem identification, ideation

1   INTRODUCTION
Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT) has been promoting 21st Century learning and skills-based education [1]. In 2018, MEXT introduced the *Period for Inquiry-Based Cross-Disciplinary Study* for inquiry-based learning. This subject focuses on interdisciplinary and integrative learning to help Japanese students develop 21st Century skills such as critical thinking and problem-solving. The objectives of the *Period for Inquiry-Based Cross-Disciplinary Study* are (1) acquiring problem-finding and problem-solving knowledge and skills, (2) finding real-world problems and research-related information and proposing appropriate solutions, (3) developing independent and cooperative learning [2]. Design thinking has the potential to prepare students to solve future challenges by fostering 21st Century skills. The SDGs Design School in Kyushu University, Faculty of Design, collaborated with Fukusho High School to develop and implement a design-based project called the *SDGs Challenge Project* for all 3rd grade students in 2021. SDGs refer to sustainable development goals promoted by UNESCO (United Nations Educational, Scientific and Cultural Organization). The project adopted the product design process and required the students to solve design problems related to the SDGs. The objective of this project is to develop students' 21st Century skills and awareness of sustainability. The *SDGs Challenge Project* was implemented in the *Period for Inquiry-Based Cross-Disciplinary Study*. The project was designed for 18 weeks, with a lesson duration of 100 minutes per week. A key challenge faced was that various subject teachers are drafted for this project and were not trained in design education. The study aims to clarify the necessary interventions for supplementing teachers' knowledge and skills related to the design process to facilitate the *SDGs Challenge Project*.

2   LITERATURE REVIEW
The *SDGs Challenge Project* adopted design thinking as key approach towards problem solving in teaching students solve sustainable related problems. This section first provide justification of adopting

design thinking as an approach to teaching problem solving. Then after, the current issues with implementing Education for Sustainable Development (ESD) in Japanese schools will be reviewed.

2.1 The significance of design thinking in Education

Design thinking is defined as an analytic and creative approach to solving wicked problems whose solutions should be solved by multidisciplinary means. It identifies users' needs through iterative cycles of feedback to test and refine prototypes [3]. Adopting design thinking as the foundation for a pedagogical framework in schools has been shown advantages in student development [4]. A research study conducted in Singapore showed that teachers acknowledge the benefits of design thinking in improving students' abilities. Design thinking helps enhance creativity, problem-solving, communication, and collaboration skills. Moreover, it aids in developing empathy and compassion among students toward their communities [5].

2.2 Current challenges of ESD in Japan's school education

As a vehicle for promoting ESD in Japan, schools associated with UNESCO Associated School Project Network (ASPnet) and Super Global High School (SGH) have been integrating ESD into their school programmes. One example is School A, a university-affiliated high school mentioned by Fredriksson et al. [6]. School A is an ASPnet and SGH-designated school that offers integrated courses with a cross-disciplinary approach that provide a variety of electives subjects where students can study. The integrated courses are integrated with ESD concepts to some extent. While School A adopts a multi-disciplinary approach in implementing the programmes, some teachers lacked a clear understanding of ESD concepts. Thus, teachers' commitment to the ESD programme was different.

In one of the Learning Innovation (未来の教室) projects, Sakaki High School and Karuizawa High School in Nagano Prefecture collaborated with Life is Tech (an IT and programming education service company) to implement a problem-solving project in the Period for Inquiry-Based Cross-Disciplinary Study [7]. Some objectives of the project are to develop students in problem-solving and awareness of sustainability. Some key issues surfaced in this collaboration between industry and schools. The training and involvement of teachers other than the teacher in-charged remained a work in progress. For the two schools to run the programme by themselves, they will have to address the needs of teacher training, usage of teaching resources for the project, technical support, collaboration with external personnel, etc. The cases above provided examples of implementing issues for problem-solving projects related to sustainable development. As an example, the current study on the SDGs Challenge Project can be a valuable case study for public high schools seeking to implement sustainable related problem-solving projects in their school programmes.

3   RESEARCH METHODOLOGY

The research question for this study is set as follows: What difficulties do teachers face in the design process when facilitating the *SDGs Challenge Project*? The study employed a qualitative research approach using the *SDGs Challenge Project* implemented in the *Period for Inquiry-Based Cross-Disciplinary Study* in Fukusho High School as a case study. Quantitative and qualitative methods for data collection were used. The study participants were teachers facilitating the project in 2021 and 2022. In 2021 and 2022, 27 teachers were involved, respectively. Some of the teachers in this project were again involved in 2022. In this project, students were tasked to find problems in their daily lives and relate them to SDGs. After selecting a problem that they were interested in, students researched to understand the problem. Through the design thinking process, students then generated ideas to solve the problems. There were no restrictions on the kind of solutions students could propose. Teachers involved in this project were from different subject backgrounds and were not trained to facilitate design thinking activities. As Fukusho High School is a public and non-specialist school, as such, subject teachers are not trained to teach design. Teachers with some knowledge about design are art teachers where students learn some form of design during art lessons. Refer to Table 1. Various instructional resources were provided to support teachers in facilitating the project. Refer to Table 2. An example of worksheet used by students is shown in Figure 1.

A pre-project survey is conducted before the start of the project, and post-lesson surveys are conducted after each lesson, from lessons one to seven, which cover the problem identification and ideation stage in the design process. The types of questions and the rationale for the pre-project and post-lesson surveys are shown in Table 3. The Likert scale items 1 (Not at all) to 5 (extremely high) and open-ended

questions are used in the survey. The Likert items are analysed using descriptive statistics. Open-ended responses were analysed, categorized, and interpreted to look for connections in teachers' perceptions.

Table 1. The profile of teachers who participated in the SDGs Challenge Project

Years	No. of Participants	Subjects	Teachers who participated twice
2021	27	Japanese Language (5), Mathematics (2), English Language (4), Social Studies (5), Science (4), Health and Physical Education (4), Arts (1), Home Economics (2)	0
2022	27	Japanese Language (5), Mathematics (3), English Language (4), Social Studies (2), Science (1), Health and Physical Education (3), Arts (2), Home Economics (2), Business (5)	10

Table 2. Types of instructional resources provided to support teachers

Resources	Type of resources	Resources objectives
Online Resources	Explanation videos	Explanation of the design process and design methods.
	Pre-lesson slides	Providing teachers with an overview of each lesson's content.
	Post-lesson slides	The coordinator created slides to answer the questions the teacher had in the questionnaire after the lesson.
Paper Resources	Lesson plans	Providing an overall summary of the project and outline the tasks that need to be completed in each lesson.
	Student worksheets	It offers teachers and students a form in implementing the tasks. Teachers need to teach from the worksheet section and the students need to fill in the tasks in the worksheet in class.

(a)   (b)
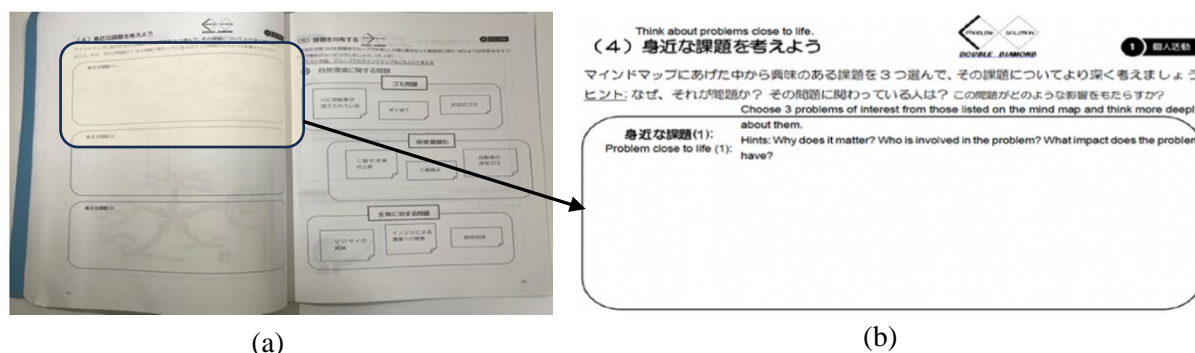
Figure 1. (a) An example of the student worksheet booklet provided to students; (b) A more detail view on part of the worksheet where students write down the problem their identified

Table 3. Question types and rationale of questions in the pre-project and post-lesson survey

No.	Question types	Questions in Pre-project survey	Reasons for setting questions
1	Likert scale items, 1-5	What's your level of understanding in design thinking?	Finding out whether design-based activities can be advanced when teachers do not have design education experience before.
2		What's your level of experience in teaching related to design?	
3	Close-ended question	What's your main subjects?	Collect the basic information about the teachers.
4	Open-ended question	Please write down your concerns when SDGs Challenge Project is implementing.	Discover what concerns teachers without design education have before conducting the project.
No.	Question types	Questions in Post-lesson surveys	Reasons for setting questions
1	Open-ended questions	Please describe any difficulties you have had in facilitating.	Finding out what difficulties teachers without design education have in facilitating design-based activities.
2		Please write down if there are anything you want the coordinator or teachers at K University to support you in next week. Or suggestion.	

4   FINDINGS

In the pre-survey, 24 responses were received for 2021 and 2022, respectively. The responses collected are presented in Figure 2. Regarding the understanding of design thinking, teachers who indicated that they had no understanding of design thinking were much lesser in 2022 than in 2021. Teachers who indicated they slightly understood design thinking increased in 2022. However, very few teachers perceived that they had a good understanding of design thinking. Regarding teaching experience, similarly, teachers who perceived that they had no experience in teaching related to design had decreased in 2022 compared to 2021. In addition, teachers who perceived they had little teaching experience in design increased in 2022. However, very few teachers indicated they had rich teaching design experience. Table 4 shows the teachers' concerns about the design process in 2021 and 2022. From the teachers' feedback, their concerns were categorized into key concern factors. In terms of lacking content knowledge about the design, teachers' concerns include the lack of understanding of design thinking and concrete implementation of design activities. Feedback related to not knowing how to monitor progress, anxiety about supporting and facilitating the students, unsure of facilitating students and fear of interfering too much were considered a lack of facilitation skills. When teachers responded that they

lacked knowledge of the project, were inexperienced with the project, and lacked understanding of the project, these concerns were categorized as unaware of the project's content.
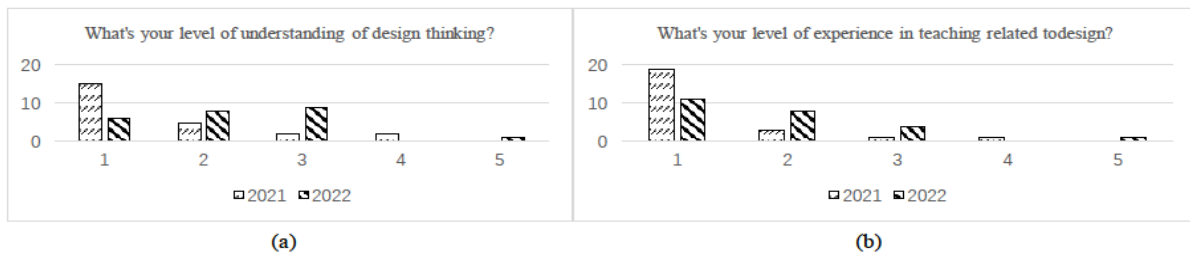

Figure 2. (a)Teachers' level of understanding of design thinking (b) teachers' experience in teaching design thinking

Table 4. Teachers' concerns of the design process during the project in 2021 and 2022

Years	Concerns about design process	Key concern factors
	Q: Please write your concerns when SDGs Challenge Project is implemented.	
2021 (n=24)	• Lacking in the understanding of design thinking. • The extent that teachers will be involved and how they monitor progress when facilitating the project. • Lacking knowledge of the project and anxious about facilitating. • Anxious about supporting and facilitating the students. • Fear of interfering too much with students and unsure of facilitating students. • Concrete implementation of the design. (Problem identification.)	• Lack of knowledge about the design process. • Lack of facilitation skills.
2022 (n=24)	• Although participated once before, still lacked an understanding of the design process and was unsure of facilitation and pedagogical skills. • In-experience with the project and am anxious about facilitating. • Lacking the understanding of the project.	• Unaware of the content of the project.

Table 5. Difficulties of design process teachers had from Lesson 1 to 7 in 2021 and 2022

Design Process	Lessons		Teachers' difficulties related to the design process from Lesson 1 to 7 in 2021 and 2022
Problem Identification	Lesson 1 Students are divided into groups; Exploration of problems and sharing.	2021 (n=17)	• Do not know how to advise students when they are confused. • Teachers were unaware of the assignment done by students. • Students do not understand the KJ method despite having been taught them.
		2022 (n=17)	• Guiding students to narrow down the problem. • Students don't understand the tasks in the worksheet. • Teachers lacked critical thinking to select useful information.
	Lesson 2 Selection of problem; Refine the identification of the problem	2021 (n=21)	• Lacking facilitation skills. • Students were not active in group work and lack motivation. • Lacking the understanding of the problem identification process. • Unclear about the instruction of the worksheet provided. • Students were not able to connect the concepts. • Need for teachers' guidebook with examples and model answers.
		2022 (n=9)	• Teachers need more examples in the worksheet. • Unclear about the instruction of the worksheet provided. • Seek help from the design faculty member.
	Lesson 3 Research on a selected problem	2021 (n=16)	• Difficulties in monitoring students' progress • Seek help from the design faculty member. • Students lacking in research skills. • The students 'interest level was different.
		2022 (n=13)	• Unclear about the instruction of the worksheet provided. • Not knowing the time to intervene in student discussion. • Students lack research methods. • Different progress among different groups. • Seek help from the design faculty member.
	Lesson 4 Sharing findings; Identification of targets related to the problem	2021 (n=17)	• Difficulties in determining the target users and stakeholders. • Difficulties in providing advice to students. • Students were not active in group work and lack motivation. • Difficulties to choose the problem and come up with a specific solution. • Seek help from the design faculty member.
		2022 (n=7)	• Guiding students to discard preconceptions and find the problem.
Ideation	Lesson 5 Research on existing solutions	2021 (n=13)	• Difficulties in determining the target users and stakeholders. • Students lacking in research skills.
		2022 (n=5)	• Nothing in particular.
	Lesson 6 Ideation	2021 (n=13)	• Guiding students to generate detailed ideas. • Seek help from the design faculty member. • Teachers provided too much advice. • Lacking teaching strategies and understanding of design process.
		2022 (n=4)	• Asking the question to students about their problems. • The students 'interest level was different. • Students cannot understand the meaning of target users.
	Lesson 7 Selection of ideas; Poster making	2021 (n=9)	• Guiding students to generate creative solutions. • Unclear how to create the concept poster for solutions.
		2022 (n=5)	• Expect more opinions from design faculty members. • Different progress among different groups.

From each post-lesson survey, the challenges teachers faced in the problem identification and ideation stage and the number of responses is presented in Table 5. The key challenges faced by teachers can be summarized as follow. During problem identification, teachers lacked understanding of the process. They found it difficult to guide students to narrow the problems into specific details, and they sought

help from members of Kyushu University. Teachers also faced challenges in advising students in problem identification and monitoring students' progress as some students lacked motivation in their work. Regarding the worksheets, teachers mentioned that the instructions in the worksheet were unclear, and students did not understand the tasks required. Teachers also suggested having a guidebook with examples and "model" answers for the tasks in the worksheet. Lastly, students lacked research skills and faced difficulties determining the target users and stakeholders.

In ideation, teachers struggled to guide students to generate creative solutions and detailed ideas. Some teachers provided too much advice or found it difficult to guide students in the ideation process, thus displaying the possible lack of teaching strategies. Some teachers lacked understanding of the designing process and sought help or opinions from members of Kyushu University. Teachers were also unclear on how to create the concept poster for the solutions. Lastly, teachers found that students lacked research skills in the ideation process.

5 DISCUSSIONS AND LIMITATIONS

From the pre-project survey, an indication of an increase in the level of understanding in design thinking and related teaching experience may be attributed to the availability of instructional and online resources in 2021. Also, considering there were teachers who participated twice, this suggested that repeated participation may familiarize teachers with the design process. However, many teachers still indicated little understanding of design thinking and related teaching experience. Perhaps, explanatory notes on how to use the worksheets, and lesson videos showing exemplary teachers who had facilitated the project well may be required as a form of resource. While conducting professional development for teachers before the project start may be useful [8], teachers can also practice self-reflective exercises after every lesson to reflect on good and bad practices as a form of learning to improve teaching and learning skills [9]. While a briefing session was conducted before the project, it is good to create opportunities for "experienced" teachers to share knowledge with teachers who newly joined the project.

Teachers' key challenges in the problem identification and ideation process are as follows. First, teachers may lack facilitation skills and may be attributed to being used to using teacher-centred approach. They are often not sure how to advise or when they should provide answers. Teachers may address facilitation issues by using questioning techniques to guide students to surface problems [10]. Second, teachers may lack sufficient understanding of the problem identification and ideation process. Thus, teachers were unable to give students timely feedback on their questions and monitor students' progress. They faced difficulties advising students to narrow down the problem and guiding them to generate creative and detailed ideas. Third, teachers may lack content knowledge and skills to help students to complete the tasks required in problem identification and ideation. In the design process, different groups of students will require different knowledge and skills to engage in different design problems. When students lack research methods and have difficulties determining the target users and stakeholders, teachers are unable to guide students to accomplish their goals. The reason may be related to teachers' lack of the content knowledge and skills required to facilitate different groups of students working on different problems. Fourth, teachers were not involved in creating the worksheets and may subsequently led to a lack of understanding of the use of the worksheets. Some teachers did not understand the necessity of some activities. Perhaps teachers' involvement in designing the worksheets are necessary.

Several key interventions may be suggested to address teachers' challenges. Professional development to train teachers before the project will be necessary. However, providing professional training can be hampered by constant personnel changes and time constraints. Teachers are rotated to other schools about every 5 years. Incoming and outgoing of teachers often occurs close to the new academic year, this poses significant challenges to finding the best time to conduct professional training. Instead of organizing professional training, providing timely educational resources for teachers to facilitate the project may be a more feasible solution to address their difficulties.

Teachers need to consider the learning content, pedagogy, experience of learning, tone of the environment, and assessment when planning lessons to raise engagement in the classroom [11]. Some teachers may also lack the necessary pedagogy and learning content. When designing a set of educational resources for the project, the considerations are as follow. First, resources should include students-centred teaching strategies, such as questioning techniques, to help teachers facilitate the activities. Second, resources should support teachers' understanding of problem identification and the ideation process. Understanding the design process will allow teachers to understand that design problem is ill-defined and that solutions are unlimited. Hence, teachers may be able to monitor students'

progress and give timely feedback. Third, resources are needed to support teachers' knowledge [12]. Resources should also contain the content knowledge and skills to help teachers guide students to complete the tasks. Moreover, resources should also inform teachers of the reasons for each task. Lastly, exemplars are necessary for teachers to know the expected outcomes of students' activities.

The limitation of the study is that in 2022, the number of teachers who responded to the 2022 post-lesson surveys was much fewer than in 2021. As such, we could only analyse the difficulties faced by teachers who had responded to the questionnaire. Additionally, there is a lack of clarity on the specific targets and benchmarks that students should aim for in their solutions. In general, students present policy related proposals or technological innovations as part of their ideal solutions.

6   CONCLUSIONS

The purpose of this study is to clarify the necessary interventions for supplementing teachers' knowledge and skills related to the design process to facilitate the design-based learning activities in the *SDGs Challenge Project*. It can be suggested that educational resources for teachers are necessary. The following aspects should be considered for the educational resources: First, it should have teaching strategies to guide student-centred learning. Second, it should include knowledge of the design process and design method. Third, the worksheet should be redesigned and introduce the meaning of the tasks in the worksheet. Lastly, exemplars should be provided in the educational resources for teachers to know the expected outcomes of students' activities.

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