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INTERVENTIONS REQUIRED TO SUPPORT JAPANESE HIGH SCHOOL TEACHERS TO FACILITATE DESIGN-BASED PROJECTS

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ABSTRACT
This study aims to clarify the necessary interventions to support Japanese high school teachers in facilitating problem identification and ideation in design-based learning. The SDGs Challenge Project in Fukosho High School was studied as a case study. This study analysed teachers' feedback before programme implementation and post-lesson surveys. The findings suggested that professional development for teachers before implementing the programme is necessary. Such professional development should focus on developing pedagogical competencies required to lead the design process, abilities to provide students with just-in-time knowledge and skills, and a good understanding of the nature of the design process.

Keywords: Design education, design process, problem identification, ideation, teacher training

1 INTRODUCTION
The Course of Study (curriculum guidelines) is revised in a recent educational reform in Japan to focus on competencies-based education. Competencies are defined by the "holistic qualities and abilities that include not only knowledge but skills and attitudes." [1]. The qualities and abilities, anchored mainly by National Institute for Educational Policy Research's 21st century competencies (21CC) framework, are (i) independence and autonomous action, (ii) relationship-building ability, (iii) problem-solving skills, (iv) the ability to utilize information technology, (v) the quality/ability to live with globalization, and (iv) the practical ability to act for a sustainable society.
Design education as a form of general education can develop 21CC in students [2]. At the moment, design education is not available in the curriculum of Japanese high schools. In 2021, the SDGs Design School in Kyushu University, Faculty of Design, and Fukusho High School collaborated to develop and implement a school-wide design-based learning programme, the *SDGs Challenge Project*, for all 3rd grade students. The aim was to develop students in 21CC, social-emotional learning and increase SDGs (Sustainable Development Goals) awareness through design activities. In order to integrate the *SDGs Challenge Project* into the school curriculum, lesson time for the *Period for Inquiry-Based Cross-Disciplinary Study* was used to adopt the project.
The *Period for Inquiry-Based Cross-Disciplinary Study* is an inquiry-based subject in Japanese high school curriculum where each school can set its objective, learning outcomes, and content. According to the Course of Study, the subject should provide cross-disciplinary and integrative learning opportunities. The overarching objectives of the subject are,

- acquire knowledge and skills necessary to solve real-world problems and propose appropriate solutions to the problems
- develop independent and cooperative learning
- develop the attitude to create new values and a better society

The overarching objectives of *Period for Inquiry-Based Cross-Disciplinary Study* make it an ideal platform to adopt the *SDGs Challenge Project* into the school curriculum. Lessons for the *Period for Inquiry-Based Cross-Disciplinary Study* occur in the school timetable once a week—the curriculum time for each lesson is 100 minutes. The *SDGs Challenge Project* was designed as an 18-week programme that spans from 13 April 2021 to 26 October 2021. During the 18 weeks, students would go through the design process to identify authentic problems, generate appropriate ideas to solve the problems, present their solutions and write a report.

The current study is part of extensive research to find out how design-based learning may be introduced and implemented in the school curriculum of Japanese high schools through the *Period for Inquiry-Based Cross-Disciplinary Study*. Using the *SDGs Challenge Project* as a case study, this study aims to clarify the necessary interventions to support Japanese high school teachers to facilitate the process of problem identification and ideation in design-based learning. In an education landscape where design education is not available, the value of this study will provide crucial insights for Japanese high schools to explore how design education may be introduced and implemented as a school-wide programme.

2 LEARNING THROUGH DESIGN: A LITERATURE REVIEW

Based on the concepts of "designerly ways of knowing", design education can be delivered as a form of general education [3]. As a form of general education, design education is non-vocational, and it focuses on developing a) abilities to solve real-world problems which are ill-defined, b) thinking skills, and c) non-verbal thought and communication abilities. Design as general education can be articulated in the form of subjects in the school curriculum, or design may be used as a general strategy for teaching and learning of subject knowledge and content [4][5].

Design education as general education can be articulated in the form of a school subject, such as Design and Technology (D&T) or Technology (TE), in the school curriculum in Europe, America, Oceania and Asia. In D&T and TE, students often learn through design projects. In design projects, students used the iterative nature of the design process to identify the needs or opportunities for change, conduct research and investigation, ideas generation, development and refine ideas, engage in critique, and experimentation through model making and prototyping [6][7][8].

As an educational pedagogy for classroom teaching and learning, design methods and pedagogy of design education are used in design-based learning to teach content knowledge and thinking skills in schools [9]. In design-based learning, students are engaged in the process of inquiry and reasoning to generate innovative solutions to solve real-world problems [10]. For example, design-based learning can be found in programmes to foster science concept learning in elementary, junior high (secondary), and high (senior secondary) schools. Some prominent programmes are such as Learning by Design (LBD) [11] and Design-Based Science (DBS) [12]. Some of the common characteristics of LBD and DBS are that students are given meaningful and authentic design challenges that motivate students to learn science concepts and use the design process to provide key learning experiences. Based on the literature reviews, design-based learning in this study adopts the definition that the design process is used to engage students in solving real-world problems to develop new content knowledge and skills and make connections between different subject areas.

3 RESEARCH METHODOLOGY

To clarify the necessary interventions required, the key research question is as follows.

- What challenges do high school teachers face when facilitating the problem identification and idea generation phase of the design-based learning activities?

The current study employed a qualitative research approach to build a case study around the *SDGs Challenge Project* implemented in the *Period for Inquiry-Based Cross-Disciplinary Study* in Fukusho High School. In this study, research strategies from quantitative and qualitative methods are being used. The participants for this study were 27 Fukusho High School teachers who were deployed to teach the *Period for Inquiry-Based Cross-Disciplinary Study* for 3rd grade students in 2021. These 27 teachers deployed were mainly of different teaching subject backgrounds, and none were trained in facilitating design-based learning. Refer to Table 1. To create opportunities for cross-disciplinary learning, two or three teachers from different teaching subjects were teamed together to facilitate a class.

Table 1. Distribution of subject teachers facilitating the SDGs challenge project

Subject Area	Japanese Language	Mathematics	English Language	Social Studies	Science	Health and Physical Education	Art	Home Economics
Number of Teachers	5	2	4	5	4	4	1	2

All 3rd grade high school students, about 314 students, participated in the *SDGs Challenge Project*. The 314 students were divided into 13 classes based on their interest in issues related to SDGs. Each class consists of about 20 to 30 students. In each class, students worked in groups of 4 to 6 members. All the participating students had little or no experience in design-based learning activities.

Before implementing the project, all teachers received a set of instructional materials which they could use to prepare each lesson. The instructional material contains lesson plans, simple explanatory notes, and student worksheets for each student activity. To further support teachers' preparation and facilitation of the activities during the lessons, a resource webpage was created to contain materials such as videos explaining the design process, problem identification, brainstorming methods, and idea generation. After each lesson, the programme coordinator would clarify teachers' inquiries and concerns by posting his advice on the resource webpage.

The study objects came from questionnaire surveys done by the teachers. A pre-commencement survey and post-lesson surveys for Lessons 1 to 7, which involved problem identification and idea generation processes, were conducted. Refer to Table 2. The questionnaires consisted of 5-point Likert items and open-ended questions. Descriptive statistic method is used to analyse the Likert items. The open-ended questions are analysed by first doing an initial immersion into the data to read and review the data. Then, the responses are categorized and interpreted to look for patterns or links in teachers' perceptions.

Table 2. The schedule of programme and questionnaire survey implementation

Date	Key Program Schedule & Outline	Survey Implementation
6 April 2021	Program Meeting with Teachers • Briefing of lesson schedule by program coordinator in Fukusho High School • Addressing key concerns before commencement of program	Pre-Commencement questionnaire survey conducted using google form
6 April 2021	• Program resource website created by program coordinator released to teachers	
13 April 2021 Lesson 1	• Program briefing for all 314 students • All 314 students moved into their respective groups of 5-6 students • Exploration of problems and sharing of problems	Post-Lesson 1 questionnaire survey conducted using google form
20 April 2021 Lesson 2	• Selection of problem and refine the articulation of problem	Post-Lesson 2 questionnaire survey conducted using google form
27 April 2021 Lesson 3	• Research on selected problem	Post-Lesson 3 questionnaire survey conducted using google form
18 May 2021 Lesson 4	• Sharing on research findings • Identification of target users and stakeholders related to the problem	Post-Lesson 4 questionnaire survey conducted using google form
8 June 2021 Lesson 5	• Research on existing solutions	Post-Lesson 5 questionnaire survey conducted using google form
15 June 2021 Lesson 6	• Idea generation	Post-Lesson 6 questionnaire survey conducted using google form
22 June 2021 Lesson 7	• Selection of ideas • Production of concept poster	Post-Lesson 7 questionnaire survey conducted using google form

4 FINDINGS & DISCUSSIONS

4.1 Pre-commencement survey

In the pre-commencement survey, 10 questions were structured to clarify five key areas: a) teachers' experience in teaching content areas outside their teaching subjects, b) teachers' experience in conducting problem solving and group work related lessons, c) teachers' level of understanding on SDGs and design, d) usefulness of instructional materials created for this programme, and e) other concerns. Responses from questions with Likert Items (Not at all=1 to extremely high=5) are presented in Figure 1. Responses from open-ended questions (Q8 and Q10) are presented in Tables 3 and 4, respectively.

Most teachers were not very experienced in conducting problem-solving and group work lessons. Teachers' in-experience may explain the low confidence perceived by most teachers in facilitating group work. The majority of the teachers expressed a lack of content knowledge in SDGs, reflecting their in-experience in teaching SDGs related lessons. In addition, most teachers had very little understanding of design thinking, and most of them had no experience in any form of teaching related to design. In terms of support, most teachers found the instructional materials provided easy to understand.

Question 8 in the questionnaire clarified teachers' current perceptions of design by asking teachers to provide three keywords that may describe design. Refer to Table 3. Most keywords provided by the teachers were relevant and can be grouped into four areas shown. Teachers' understanding of design relates mainly to design specialization and design abilities based on Question 8.

Students' engagement in learning may be influenced by five key factors: pedagogical competencies, creating meaningful learning experiences, content knowledge, assessment for learning, and setting the tone of the environment [13]. Pedagogical competencies may be related to using strategies to manage instructions to help students learn and understand concepts and content and develop skills. Creating meaningful learning experiences involves helping students acquire a deep understanding of what they learn and develop as self-directed learners. Content knowledge is related to the content that students will

learn. Assessment for learning is the ability to determine students' level of mastery in their learning and provide timely feedback to improve students' learning. Setting the tone of the environment involves creating the environment to allow students to make decisions, express themselves, promote cooperative learning and develop active learning. When analysing teachers' concerns in Question 10 in the questionnaire, their concerns can be associated with the five key factors mentioned above. Refer to Table 4.

Figure 1. Responses of teachers for Likert items questions

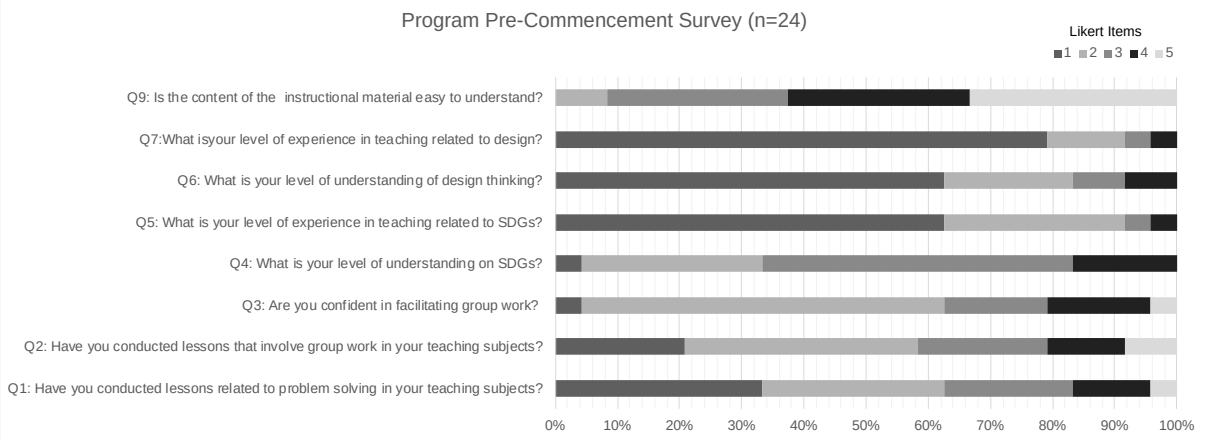

Table 3. Teacher's perception of design

Table 4. Teacher's key concerns in conducting the programme

Q10: Please provide any concerns you may have about the conducting the SDGs Challenge Project. (n = 24)					
Key Concerns from Teachers (✓ will be indicated in those key factors that may be associated to the teachers' concerns)	Teachers' concerns may be associated to the factors below:				
	pedagogical competencies	creating meaningful learning experience	content knowledge	providing assessment for learning	setting the tone of environment
not experience in group work and lacking in understanding on SDGs and design thinking	✓		✓		✓
in-experience in design-based projects	✓				
the extent of teachers' involvement during the facilitation, and how to monitor students' progress	✓	✓		✓	✓
lacking knowledge in implementing the lessons and anxious about conducting the lessons	✓	✓	✓	✓	✓
not used to facilitating group work in class and conducting discussions to guide students, and fear of interfering too much into students' work	✓	✓		✓	✓
students may not be able to manage their learning and complete their tasks		✓			
inability to set meaningful topics		✓			
lacking content knowledge on SDGs which may result in the inability to provide good advice			✓	✓	
managing students' progress				✓	
Inability to draw out students' interest		✓			

4.2 Post-lesson surveys

In all the post-lesson surveys from Lesson 1 to 7, three key questions were used to elicit teachers' responses to instructional materials and their challenges during problem identification and idea generation. Using 5-point Likert items (strongly disagree=1 to strongly agree=5) for the questions, refer to Figure 2, teachers were optimistic about the instructional materials provided.

When asked about challenges faced during lessons through an open-ended question, refer to Table 5; teachers generally face difficulties in providing advice to students when facilitating the problem identification and the idea generation processes. They also face challenges in managing the progress and motivations of different groups of students. Other challenges that may need to be addressed as a priority were as follow. In the problem identification process, teachers lacked sufficient understanding of the problem identification process. They were facing challenges in guiding students to break down the larger aspect of the problem into specific problems. In addition, teachers found that students lacked the research skills to understand the problems through research. For example, students found difficulties determining the target users and stakeholders related to the problems. During idea generation, teachers

faced challenges guiding students to generate creative solutions. Some may also have provided too much advice to students instead of directing them toward the solutions. Teachers were also not familiar with creating concept posters for selected design solutions.

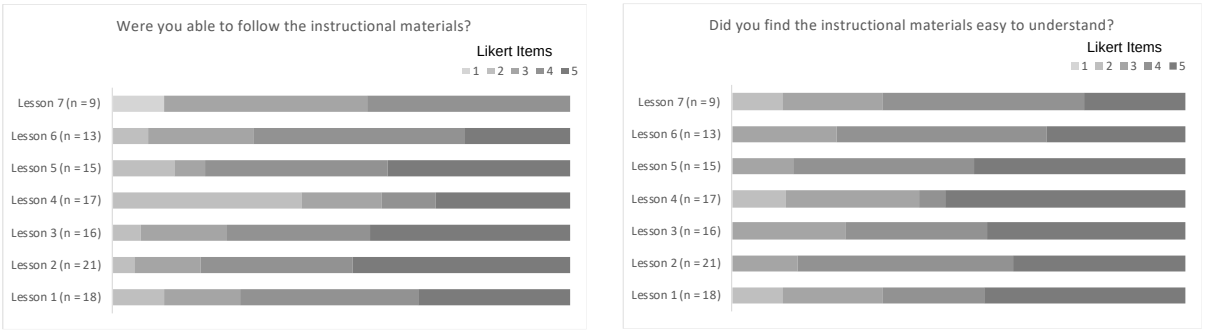

Figure 2. Teachers' feedback on instructional materials

Table 5. Challenges faced by teachers from Lesson 1 to 7

	Please describe any difficulties you have had in teaching.	
Design Process	Lessons	Key issues
Problem Identification Process	Lesson 1: Exploration of problems and sharing of problems (n= 18)	• Teachers unaware of the pre-program preparations done by students • Students were not active in group work and collaboration skills • Students were not able to group their concepts about the problems even though they were taught
	Lesson 2: Selection of problem and refine the articulation of problem (n = 21)	• Need of teacher's guidebooks with model answers • Lacking in facilitation skills • Lacking competencies in information communication technology • Lacking in the understanding of problem identification process • Students were not active in group work and collaboration skills • Some students were lacking in motivation • Students find difficulties in connecting concepts • Unclear instructions in the instructional materials provided
	Lesson 3: Research on selected problem (n = 16)	• Interest level of students varies • Students lacking in research skills • Difficulties in monitoring progress of students • Some students were not engaged
	Lesson 4: Sharing on research findings; Identification of target users and stakeholders related to the problem (n = 17)	• Difficulties in determining the user targets and stakeholders • Difficulties in providing advice • Students were not active in group work and collaboration skills • Some students were lacking in motivation • Students lacking critical thinking skills
Idea Generation Process	Lesson 5: Research on existing solutions (n = 15)	• Students lacking in research skills
	Lesson 6: Idea generation (n = 13)	• Ideas were too abstract and lacking in detail • Teachers provided too much advice • Different progress among different groups • Students did not know about their objectives
	Lesson 7: Selection of ideas; Production of concept poster (n = 9)	• Ideas generated were too similar to existing solutions • Unclear how to create the concept poster of the solution

4.3 Implications on interventions required

Based on the pre-commencement survey and the post-lesson surveys, several implications for necessary interventions may be presented. Although providing instructional materials and support via the resource webpage may be helpful for teachers during the implementation of the project, professional development before starting the project may prepare the teachers better to lead and facilitate the design process. In professional development, teachers should be prepared in the following aspect. Firstly, developing teachers' pedagogical competencies in teaching and facilitating the design process is necessary to guide students navigate the design process. In addition, strategies such as questioning techniques would be helpful for teachers to guide students to ask meaningful questions so that students can be self-directed to find relevant answers and make meaningful decisions in the design process. Secondly, while teachers may feel that they lack content knowledge, it should be noted that in the design process, different groups of students will require a different set of knowledge and skills to engage the design problems. Thus, teachers' ability to provide just-in-time knowledge and skills to students is essential. Just-in-time knowledge and skills refer to knowledge and skills that students require to complete the tasks required in particular design problems or solutions. Thirdly, a good understanding of the design process will be crucial. The reason is that teachers will then be able to guide students through the iterative nature of the design process. Knowing the nature of the design process will allow teachers to understand that design problems are ill-defined and solutions are not limited to one. As such, teachers may be able to monitor students' progress, and give timely feedback and provide scaffolds to direct students through the design thinking processes in design-based learning.

5 CONCLUSIONS

This study aims to clarify the necessary interventions required to support Japanese high school teachers to facilitate the process of problem identification and ideation in design-based learning. In a context where none of the teachers were trained to facilitate design-based learning activities, it can be suggested that professional development of teachers before the commencement of design-based learning is necessary. The following aspects should be considered as part of the professional development. Firstly, teachers should be developed with pedagogical competencies to lead and facilitate the design process. Secondly, teachers are required to possess the ability to provide just-in-time knowledge and skills during the design process. Lastly, a good understanding of the nature of the design process is necessary to monitor students' progress and provide timely feedback and scaffolds for students during design-based learning activities.

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