

Designing Project-Based Learning to Promote the Social Construction of Knowledge by Overcoming Dissonance Using G Suite

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Abstract This study designed and evaluated a project-based learning (PjBL) technique that promotes the social construction of knowledge by overcoming dissonance using G Suite for Education. The core aspects of the design include controlling the discussion process by setting a task with the same directionality in terms of its solution while including two conflicting positions and using a synchronous system to provide real-time feedback from a teacher to control the discussion process. A four-part model of PjBL was presented to overcome dissonance. To evaluate the effects of this model, PjBL lessons were conducted with high-school students in which the topic led them to consider ideas to support people living in shelters for 3 months following an earthquake. Consequently, the effects of the core aspects of the design were partially confirmed.

Keywords project-based learning, idea creation, collaborative learning, utilizing information and communications technology

1. Introduction

The complexity of issues in society is increasing, owing to rapid developments in information technology (IT) and globalization as well as changes in social structures. *The Future of Education and Skills* is an Organisation for Economic Co-operation and Development (OECD) report on the estimated education and skills needed up-to 2030^[1]. In addition to the competencies that had already been outlined, three were added to address changing societal issues: creating new value, reconciling tensions and dilemmas, and taking responsibility^[1]. In Japan, there are continual revisions to the senior high-school courses of study^[2] to address the societal complexities brought on by information and technology and globalization so that young people can actively engage with various changes and work with others to resolve issues^[2] and to call on educators to seek learning and education approaches that embody that purpose.

Previous research has explored educational methodologies and directionalities that account for complex social issues with *dissonance* and *conflict* being identified as key concepts. For example, Yamauchi^[3] divided

active-learning methods into three levels (i.e., Level 1: knowledge sharing and rumination; Level 2: conflict and knowledge creation; and Level 3: problem setting and resolution). Knowledge creation is based on conflict being given prominence as a meaningful position. Gunawardena *et al.*^[4] highlighted the importance of the social construction of knowledge for computer-mediated communication and developed an interaction analysis model for computer conferencing (see Table 1) that can overcome dissonance (Phases II and III) and represent higher-order concepts within the framework. Thus, it was positioned as an important learning process for complex social issues, which is in line with the OECD's reconciling tensions and dilemmas^[1].

Therefore, it is necessary to determine the types of educational methods most suitable for promoting the

Table 1. Interaction analysis model for examining the social construction of knowledge in computer conferencing according to Gunawardena *et al.*^[4]

I	Sharing/comparing of information
II	The discovery and exploration of dissonance or inconsistency among ideas, concepts, or statements
III	Negotiation of meaning/co-construction of knowledge
IV	Testing and modification of proposed synthesis or co-construction
V	Agreement statement(s)/applications of newly constructed meaning

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social construction of knowledge to overcome dissonance. Regarding the three levels of active-learning methods, Yamauchi^[3] suggested that peer teaching and collaborative learning were examples of Level 2 and that project-based learning (PjBL) was an example of Level 3. PjBL schemes are those for which correct answers are not predetermined. Notably, the social construction of knowledge by overcoming dissonance is known to help resolve problems that have no given answer through conflict and knowledge creation. PjBL effectively uses collaborative learning to promote conflict and knowledge creation, and is considered suitable in this regard. PjBL is an educational method that has attracted attention for many years. It implements educational practices through research tasks^[5], and it requires students to pursue solutions to nontrivial problems through the following activities; asking questions, debating ideas, designing experiments, collecting and analyzing data, communicating with others, creating artifacts and so on^[5].

Other effective features of PjBL include the development of driving questions, a focus on learning goals, engagement in scientific practices, collaborations, using technological tools to support learning, and creation of artifacts^[6]. Efstratia^[7] stated that PjBL was effective in improving problem-solving and decision-making. Sasson *et al.*^[8] demonstrated that, compared with a traditional curricula, PjBL improved critical thinking and question-setting abilities.

These characteristics have led to studies that combined PjBL and information and communications technology (ICT) to promote the social construction of knowledge by overcoming dissonance. For example, Heo *et al.*^[9] implemented a PjBL program for undergraduate students, and Quek^[10] implemented one for high-school students in online environments. As shown in Table 1, both cited Gunawardena *et al.*^[4]'s interaction analysis model for examining social construction of knowledge in computer conferencing as an indicator of the social construction of knowledge that overcame dissonance and measured the effects.

Heo *et al.*^[9] suggested that Phase III (Table 1) had a positive impact on the PjBL outcomes. However, there have been problems with reaching Phase III. Lucas *et al.*^[11] reviewed 15 extant studies that promoted the online social construction of knowledge using the interaction analysis model and found that most studies remained at Phase I and failed to meet Phase II and III

objectives. The studies included some, but not all, research using PjBL and ICT. Hou and Wu^[12] similarly demonstrated the importance of Phases II and III for high-quality discussions during PjBL with synchronous systems for higher education. However, more than half of the discussions were not related to the topic, indicating that the design of PjBL remains a challenge.

Previous research conducted in high schools similarly indicated that students rarely reached Phases II and III, noting problems related to the educational methods used. Quek^[10] combined PjBL with an asynchronous online forum, coding Phases I–V for all posts on the online forum used. Phase I accounted for 82.7% of the total, Phase II accounted for 13.5%, and Phase III accounted for 3.7%. Thus, it appears that in high schools, there are issues with achieving the social construction of knowledge by overcoming dissonance. Therefore, in addition to developing PjBL that promotes Phases II and III more effectively, research must verify in detail what kind of support is effective and to what extent. Lee *et al.*^[13] also studied collaborative learning that overcomes conflicts using PjBL, positing the importance of controlling positive conflict. Lee *et al.*^[13] pointed out that task-level conflicts are productive for discussion, whereas process- and relationship-level conflicts have a negative impact, further noting that students with advanced social skills can decrease unnecessary conflicts in groups while increasing collaboration. However, there remain challenges with providing instructional approaches (e.g., teacher support) that can modulate discussion on the social construction of knowledge by overcoming dissonance.

In summary, in recent years, higher attention has been given to the social construction of knowledge in high schools by overcoming dissonance. To promote these ideas, there has been significant research related to the most effective teaching methods that combine PjBL and ICT. However, the PjBL programs that have harnessed ICT in previous studies have generally been limited to Phase I and have failed to fully achieve Phases II or III based on interaction analysis models for examining the social construction of knowledge in computer conferencing^[4]. Therefore, research into designing effective teaching methods is urgently needed.

This study designed and evaluated a PjBL technique that promotes the social construction of knowledge by overcoming dissonance.

The operational definitions and interrelations

between the significant conceptual terms used in this study are presented here. We operationally define *the social construction of knowledge* with reference to Gunawardena *et al.*^[4] as “the integrated construction of ideas in response to the dissonance discovered between learners under certain constraints, such as considering how to reconcile the values of both sides and to what extent those values should be reflected.” *Dissonance* is defined as “the conflict discovered between what learners consider to be important from their respective positions under certain constraints.” *Reconciling tensions and dilemmas*, per the OECD, are similar to the social construction of knowledge by overcoming dissonance. We also operationally define *conflict positions* as “two positions that create general dilemmas and conflicts in an area and are set to facilitate dissonance between learner-generated ideas.” Thus, conflict positions comprise a method of intervention to promote dissonance. *Integrated ideas* are operationally defined as “ideas constructed in response to the dissonance encountered between learners under certain constraints, such as considering how to reconcile the values of both sides and to what extent those values should be reflected.” This study uses these operational definitions for coding at the final stage of the descriptive data. To determine the definition of overcoming dissonance used here, the issues considered by both sides to be important must be reflected in the outcome. Beyond this aspect, a new element that connects the two perspectives must be added.

2. Designing Project-Based Learning

2.1 Design Requirements

Here, the issues that can arise when encouraging the social construction of knowledge to overcome dissonance were summarized from previous research. It has been found that, even when PjBL was conducted using synchronous online systems for discussion, most discussion content was limited to Phase I (sharing/comparing of information) according to [12]. Furthermore, ICT did not result in meaningful learning, and tandem teaching strategies were required. It is therefore important to provide carefully planned instruction rather than simply adding online systems to facilitate PjBL interactions.

These findings indicate that two design requirements are necessary to steer the PjBL discussion process in the desired direction. The first is the establishment of

tasks and lesson structures to create dissonance. Lucas *et al.*^[11] found that the main reason for the lack of transition to Phases II or III was that no meaningful tasks had been set that could give rise to dissonance and dispute.

The second design requirement is teacher feedback. Gunawardena *et al.*^[4] found that to ensure interaction and discussion directionality in Phases II and III, careful intervention was required. Therefore, the second design requirement is to control the directionality of the discussion through teacher feedback.

2.2 Designing a Project-Based Learning Model

Based on the two abovementioned design requirements, this section details the core design aspects and the PjBL model needed to promote the social construction of knowledge by overcoming dissonance.

In relation to the first design requirement, that is, to set tasks and lesson structures likely to create dissonance, Koh *et al.*^[14] commented that preparing topics appropriate to the needs and context of the learners would deepen discussions and move them toward Phase III. Other studies on argument-based computer-supported collaborative learning concluded that collaborative learning was more effective in heterogeneous groups comprising people with conflicting ideas^[15]. This indicated that it is important to present issues that are controversial, specific, and meaningful to learners to promote dissonance within the group. At least two contradictory positions should be presented. It is also important to control the discussion by establishing tasks and lesson structures with the same directionality in terms of their solution.

The second design requirement, that is, controlling the directionality of the discussion through teacher feedback, requires the development of a method of visualizing the high-level discussion processes for diverse groups and providing feedback from the teachers to the learners. A synchronous system that enables teachers to determine each group’s learning activities in real time and give appropriate feedback based on this monitoring is an example^{[16],[17]}. When synchronous PjBL systems have been used, the teacher monitored the groups’ active discussion processes in the classroom using an online chat system or similar and intervened when necessary, which further highlights the importance of using synchronous systems to control the discussion process.

Such a system must enable the teachers to structure the discussions in real time while providing feedback. This study used Google Sheets from G Suite for Education.

Based on the above, two core design aspects are defined: controlling the discussion process by setting a task with the same directionally in terms of its solution while including two conflicting positions (design aspect 1), and using a synchronous system to provide real-time feedback from the teacher and control the discussion process (design aspect 2). Table 2 lists the design model for PjBL for the promotion of the social construction of knowledge by overcoming dissonance. The design model has four parts.

The first part includes the advance preparation by the teacher, who starts by envisioning the entities that resolve issues (e.g., companies, non-profits, or local governments) and listing some real-world issues. Then, the teacher selects an issue that is both controversial and meaningful to the participants and that has contradictory positions. Next, the teacher uses a questionnaire or similar to acquire information about the learners' positions on issue resolution, after which the learners are divided as evenly as possible into small groups of about three people each to discuss the opposing positions (Positions A and B).

During the second part, the teacher creates two groups comprising all learners that support Position A and all that support Position B. These groups then independently brainstorm the reasons why their positions are important to resolving the issue. This facilitates sharing among learners holding the same position and further increases the dissonance between Positions A and B. Then, based on what the groups think is important, each group develops their own ideas for Positions A and B.

During the third part, the groups are combined into intermediate groups, after which each smaller group points out the problems from their respective position within that intermediate group. This should result in advancement by the learners to Phase II.

During the fourth part, the learners develop ideas to integrate their diverse positions, which should lead to Phase III. Later, each group gives a presentation to the entire class. Each part of the discussion structure is framed in advance and is documented in Google Sheets as the groups engage in face-to-face discussions.

The real-time teacher feedback model is described in next. Previous research has found that using synchronous systems to monitor and provide feedback on the

student discussion process can be a significant burden for teachers, because they must understand the discussions using the chat system. They must textually intervene, monitor, and then give necessary feedback while working across the multiple online communication platforms^[18]. Therefore, to reduce teacher's load, the approach described here uses Google Sheets as the sole communication tool, with the teacher giving positive or negative feedback on the discussion content using a specific colors or comments. Additionally, for the parts 2–4 activities, the teacher can set the criteria for good discussions and can identify those that need improvement (see Table 2). Hence, the PjBL can be designed to reduce the cognitive load on both teachers and the learners while controlling the discussion in real time to promote a more advanced learning process.

As Thomas^[19] noted, it is important that PjBL not be entirely teacher-led. In this model, although the structure of the lesson is largely directed by the teacher, the teacher's role is structured around facilitating the individual activities of the students and their processes of creating ideas. This model balances the two.

2.3 Lesson Design

2.3.1 Participants and Curriculum

To verify the effectiveness of this study, lessons were designed for a civics class for 18 third-year high-school students at a private high school (hereafter, "High School X") in Osaka Prefecture in Japan. High School X has adopted a *bring-your-own device* approach, and uses G Suite for Education across the school. Additionally, as group activities and PjBL are conducted every day using G Suite for Education, both teachers and students are accustomed to the activities envisioned in the given model.

The civics class was held for five class hours over one semester (12 weeks). The unit under discussion in this study took place over about 2 months from December 2019 to January 2020 while focusing on students' knowledge acquisition. This PjBL program promoting the social construction of knowledge to overcome dissonance was then conducted over five periods from January 20 to 30, 2020.

The unit topic was the simulation of a major Nankai trough earthquake, an event that is highly likely to affect the students' region in the future. Such an earthquake is expected to cause widespread damage,

including tsunamis on the Pacific coast of Japan. It is likely that many of those affected would be in the Osaka area where High School X is located. However, inland areas, such as Kyoto, are expected to suffer less damage. Therefore, a scenario was established in which the high school students lived in Kyoto several years in the future and were providing assistance in response to a major Nankai trough earthquake.

From December 2019 to January 15, 2020, the teacher taught an overview of a Nankai trough earthquake. Then, students were randomly divided into four groups and asked to collect information about past earthquakes and issues related to four topics: evacuation centers, volunteering, gathering information in the affected areas, and donations. They were asked to share their information with the class. At this time, the conflicting positions regarding supporting shelters were not taught.

2.3.2 Unit Design Based on Design Model

In the classes from January 20 to 30, 2020, the topic was specified as follows: “You are a member of a non-profit organization (NPO) working to support of earthquake recovery. The NPO, which is located in Kyoto, is run by five people having an annual budget of 10-million yen. Imagine that a major Nankai trough earthquake has occurred and propose specific ideas to improve the daily living environments of the people living in shelters 3-months post-earthquake. Choose a position on this issue that reflects your thinking on the topic and come up with some ideas, such as activities, online services, etc.”

Although earthquakes are frequent in Japan, and there are many examples of support provided to affected areas, there is a common dilemma in which one must decide to either provide support by going directly to the disaster area or to provide it remotely. The position that believes that volunteers should go to disaster areas to provide support has strong points, such as being able to provide more thorough support and supplementing the reduction in personnel. It also has negative points, such as untrained volunteers getting in the way or clashing with the victims. The positive arguments for providing support remotely espouse gathering donations and facilitating the efficient provision of supplies and financial aid. However, the negatives are that the support may not actually reach those who need it, especially within a

3-month post-disaster scenario.

These two perspectives were then set as the conflicting positions. Specifically, Position A was to advocate providing support in the disaster area (e.g., working in the disaster area as a volunteer) and Position B was to advocate providing support from a remote location without going into the disaster area (e.g., using the internet to support victims). Both positions correspond to Part 1 of the design model in Table 2.

A questionnaire was conducted on January 20 with four possible responses (i.e., Position A, basically Position A; basically Position B; Position B) to determine students’ prioritizations. The results revealed that three students definitely supported Position A; six basically supported Position A; six basically supported position B; and three definitely supported Position B. Thus, the class was divided into six groups: three groups each for Positions A and B.

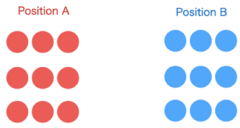
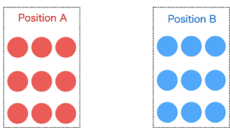
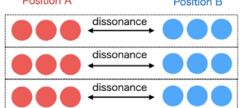
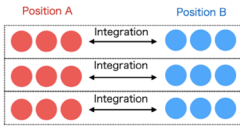
Subsequently, at the beginning of the first period, the teacher explained that the overall goal of the PjBL was to devise ideas for providing support that would overcome the dissonance between the two positions. The teacher also explained that students should regard the descriptive data derived from their ideas, including the spreadsheet discussion process, as the final outcome and target of evaluation. The teacher then explained that a blue highlighter would be used to indicate positive areas, and a yellow highlighter would be used to indicate areas needing improvement. Individual words or sentences would also be highlighted to invoke more detailed feedback.

During the first period, the teacher explained that the goal of the first period was for students to arrive at a deeper understanding of their reasons for selecting each position. The first period corresponds to the first half of Part 2 in the design model of Table 2, positioned as advance preparation for Phases II and III. Using Google Sheets with separate pages for each position (see Fig. 1), the teacher encouraged each student to write as much as possible about why they selected a particular position. The teacher provided feedback in response to their reasons. Positive reasons for their position were indicated with a blue highlighter, and negative reasons were highlighted in yellow to indicate that the student’s rationale needed improvement.

During the second period, the teacher explained that the goal was to create support ideas in accordance with each position. The second period corresponds to

DESIGNING PjBL TO OVERCOMING DISSONANCE

Table 2. Design model for project-based learning to promote the social construction of knowledge by overcoming dissonance (PjBL to overcome dissonance)

Part	Design Content	Teacher Feedback (FB)	Targeted Phase
1	 <ul style="list-style-type: none"> • Set PjBL issues that include conflicting positions • Use a questionnaire to ascertain whether students wish to resolve the issue from Position A or Position B, and then divide the students approximately in half 		Preparation (Clarifying positions)
2	 <ul style="list-style-type: none"> • Divide students into groups according to Position A or B, and have them verbalize what they think is important for that position • The small groups come up with ideas regarding what they think is important in relation to Position A or B respectively 	<p><u>Positive FB:</u> The student has written positive reasons for choosing their position, with reasons and ideas linked <u>FB indicates any need for improvement:</u> for example, when a student has simply described the other position as inappropriate and given this as their reason for selecting their own position, or their reasons and ideas are not linked</p>	Preparation (Clarifying positions)
3	 <ul style="list-style-type: none"> • The individual small groups for Positions A and B are combined into intermediate groups; the groups identify problems from their respective positions and identify points of dissonance 	<p><u>Positive FB:</u> Criticisms of the other position make sense, and are based on the position and concerns that the student has chosen</p> <p><u>FB indicating any need for improvement:</u> for example, criticisms of the other position that are not related to the position and concerns that the student has chosen</p>	I (Sharing/comparing of information) II (The discovery and exploration of dissonance or inconsistency among ideas, concepts or statements)
4	 <ul style="list-style-type: none"> • Students come up with ideas that can overcome dissonance based on a desire to value both positions with the same directionality on the issue • each group gives a presentation to the entire class 	<p><u>Positive FB:</u> Both groups' concerns are accounted for and the solution seems to serve the purpose</p> <p><u>FB indicating any need for improvement:</u> for example, it does not appear that both groups' concerns have been accounted for</p>	III (Negotiation of meaning/co-construction of knowledge)

the second half of Part 2 of the design model in Table 2, positioned as preparation for Phases II and III. The students were placed in groups of two to three having the same position. Using Google Sheets with separate pages for each group (see Fig. 1), the teacher asked students to select two or three of the most important reasons for selecting their position and to then write down ideas for providing support based on those reasons. The teacher provided feedback regarding their ideas using a blue highlighter to indicate that an idea was positive if there was a clear connection between the reason for the

selected position and the idea, and a yellow highlighter indicated the need for improvement, if it was negative.

During the third period, the teacher explained that the goal was for students to criticize the ideas for providing support based on the opposing position and to rearticulate what they valued about their own position. The third period corresponds to Part 3 of the design model in Table 2 and aims to achieve Phase II. The students then formed groups of four to six, combining two groups from different positions, and presented their ideas for providing support to each other. Then, the

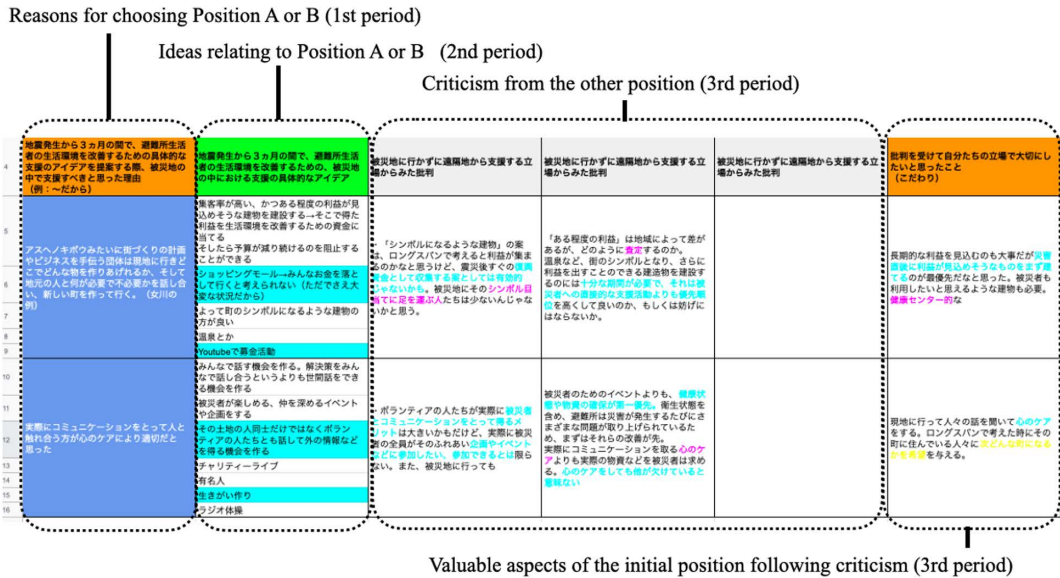


Figure 1. The spreadsheet in 1st, 2nd, and 3rd period

Valuable aspects of both positions, that appear compatible (4th & 5th period)

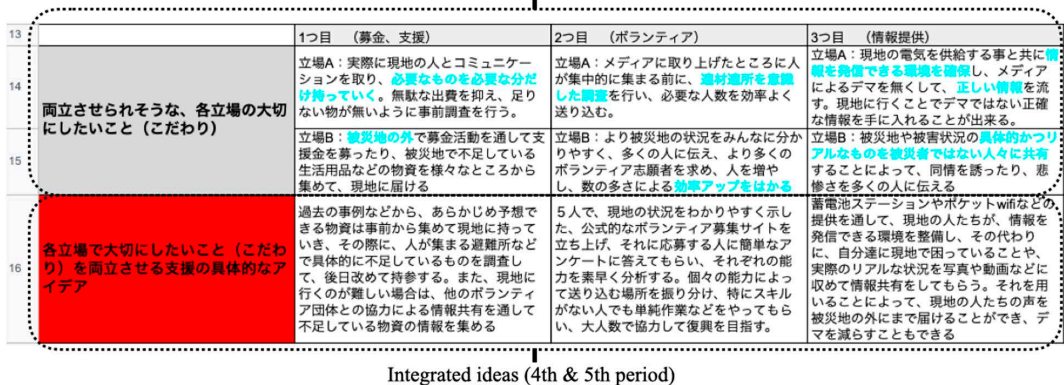


Figure 2. The spreadsheet in 4th and 5th period

teacher asked them to use the spreadsheet in Fig. 1 to write criticisms from the opposing position. Finally, based on those criticisms, the students reiterated what they valued about their own position. Regarding the students' criticisms of the opposing position, the teacher provided positive feedback using a blue highlighter if the criticisms were based on the positions and concerns chosen and indicated the need for improvement with a

yellow highlighter if not.

During the fourth period, the teacher explained that the goal was to create ideas for providing support that would integrate what the students valued about both positions. The fourth period corresponds to Part 4 of the design model in Table 2 and aims to achieve Phase III. The teacher asked students to use Google Sheets divided into pages for each group of four to six people from the



Figure 3. Students in class (Third period)

third period (see Fig. 2) to annotate what they valued about each position and to devise ideas that integrated them. The teacher indicated positive feedback with a blue highlighter if an integrated idea included aspects that the students valued from both positions and if it seemed likely to contribute to the purpose of the exercise (i.e., the improvement of evacuation shelter life). The teacher used a yellow highlighter to indicate the need for improvement if an integrated idea appeared not to include aspects that the students valued from both positions or if they seemed to be simply listing ideas without integrating them.

During the fifth period, students continued the exercise of the fourth period and finished by presenting their outcomes to the class. Similar to the fourth period, the fifth-period class corresponds to Part 4 of the design model in Table 2 and aims to achieve Phase III. Fig. 3 reflects the situation of the third period.

3. Evaluation

The evaluation was conducted from two perspectives according to two core design aspects in Section 2.2. First, we evaluated the effect of controlling the discussion process by setting a task having the same directionality in terms of its solution, while including two conflicting positions from among the functions based on design-aspect 1. This evaluation should show how effective the tasks and lesson structure are in each phase. Second, we evaluated the effect of using a synchronous system to provide real-time feedback from the teacher while controlling the discussion process during the functions based on design-aspect 2. Because it is diffi-

cult to evaluate this effect by coding based on descriptive data in the classroom, this study evaluated the effect by elaborately interviewing the students.

3.1 Evaluating the Extent of the Achievement in the Discussion Phases

To evaluate the extent to which the discussion phases were achieved, the responses on the sheets for each group from the first to fifth periods were extracted and linked to the final ideas integrated during the fifth period ($N = 9$, three each among three groups of six people).

The achievement of Phases I and II was assessed from the responses in the third period, and the achievement of Phase III was assessed from the responses from the fourth and fifth periods. The evaluation criteria were based on the coding criteria used by Gunawardena *et al.*^[4]. For example, the Phase I criteria include “statements of observation or opinion” and “asking and answering questions to clarify details of statements.” Phase II criteria include “identifying and stating areas of disagreement” and “restating participant’s positions.” Phase III criteria include “identification of areas of agreement or overlap among the conflicting concepts” and “proposal and negotiation of new statements embodying compromise, co-construction” [4, p.414]. As far as Gunawardena *et al.*^[4] is concerned, it is not necessary for all coding criteria in all phases to be met. That is, if at least one criterion were met, the relevant phase was considered to be achieved. The evaluation was conducted in consultation with the first and second authors of this paper, and conversation data were extracted from the fourth period and used as reference.

The extent to which the discussion phases were achieved was evaluated by calculating the ratio of phases reached with the final support ideas. That is, we evaluated whether controlling the discussion process by setting a task with the same directionality in terms of its solution worked, while also determining whether the two conflicting positions functioned effectively.

An example of group learning is presented here to grasp the ways in which learning actually takes place and consider their extent of effectiveness. Examples of changes in individuals’ ideas within groups before and after the PjBL are also discussed to consider the extent to which the PjBL was effective. Specifically, both before and after the PjBL, the students were given 8 min to write a free-form response to a Google Form with

ideas relating to the PjBL task. Thus, they identified specific support measures to improve the residential environment of people living in shelters.

3.2 Evaluating the Effect of the Color-Coded Real-Time Teacher Feedback

Following the PjBL classes conducted in this study, separate group interviews with the three six-person groups we conducted in which the sheets produced in the PjBL were referred to to assess the contribution of the real-time color-coded teacher feedback provided as part of the social construction of knowledge. The students were asked about the positive impact of teacher feedback, the feedback that having no impact, and the third and fourth period PjBL activities in which group knowledge construction activities had been conducted. All discussions were recorded using a voice recorder, transcribed, and used for analysis data.

The student utterances relating to teacher feedback and its influences were extracted and coded to represent the influence of the teacher's feedback, making it possible to confirm the effect of the teacher feedback on student discussion development. Therefore, it was evaluated whether design requirement 2, using a synchronous system to provide real-time feedback from the teacher and control the discussion process, had worked effectively.

4. Results

4.1 Extent of Discussion-Phase Achievement

Based on the sheets after the third period, eight out of nine (89%) of the final integrated ideas satisfied the criteria for Phase II (i.e., discovery and exploration of dissonance or inconsistency among ideas, concepts, or statements) for both Positions A and B. However, one of the responses did not progress past Phase I. Based on the Google Sheets inputs from the fourth and fifth periods, nine out of nine (100%) of the final integrated ideas satisfied the criteria for Phase III (i.e., negotiation of meaning/co-construction of knowledge).

Table 3 summarizes the descriptive data for each activity linked to the final idea created by Group 3. We can interpret that students who supported Position A wanted to provide support in the disaster area, and they valued obtaining information that could be best under-

stood on the ground. Meanwhile, students who supported Position B (i.e., providing support from a remote location without going to the disaster area) valued focusing on providing supplies and logistical support while mainly considering the efficiency of the overall support provided. Thereafter, when students were criticized from the other position, they critiqued each other's ideas based on the values of each position, so that essential conflicts emerged. Subsequently, students reiterated what both positions valued and came up with an integrated idea to achieve solutions within the constraints of a five-person team. They proposed an integrated idea that added a new element: creation of a recruitment website with a questionnaire based on on-site information, thereby enabling clear representation of the information (Position A) and volunteers to be sent to the right place at the right time (Position B). These results indicate that Phase III, that is, the social construction of knowledge by overcoming dissonance, was achieved.

Tables 4 and 5 show descriptive data from before and after the PjBL for students in Positions A and B in this group. Compared to the descriptive data from before the PjBL, as discussed in Table 3, it is apparent that, after the PjBL, students proposed considering both gathering information that could be understood only on the ground and focusing on supplies and logistical support in consideration of the efficiency of the overall support provided.

The above results indicate that this lesson encouraged the negotiation of meaning/co-construction of knowledge.

4.2 Effect of Real-Time Color-Coded Teacher Feedback

Table 6 shows the analysis results for the interviews and summarizes the effects of the real-time color-coded feedback for the third and fourth periods. Other effects seen during the first and second periods include guidance through comments toward creating elaborate ideas and guidance in selecting reasons ideas were generated.

4.2.1 Influence of Feedback During the Third Period

During the third period, the learning process developed as follows. Students received criticism based on the other group's position on the topic, and they then accepted the inadequate aspects of their initial idea.

Table 3. Group 3 discussion process and phase evaluation

	Position A	Position B	Phase
Reasons for choosing Position A or B	By gaining an understanding of the whole area (region, land, etc.) ahead of other volunteers, we can work on developing the land to minimize damage from further earthquakes.	We think it will be more efficient to let the professionals such as the Self-Defense Forces, firefighters, and doctors work in the afflicted area, while we acquire and send what people need.	—
Ideas relating to Position A or B	<ul style="list-style-type: none"> Investigate the afflicted area in advance and recruit suitable volunteers. Need to accurately provide detailed information about the kinds of buildings damaged and which areas were damaged by tsunamis and landslides. Must officially recruit suitable people so that everyone can cooperate and the volunteers can return to the status quo. 	<ul style="list-style-type: none"> Outside the afflicted area, gather clothes, food, daily necessities, and medical supplies needed by people in the afflicted area, and donate them to the afflicted area. Investigate past disasters and find out which supplies were scarce, and send what seems likely to be needed. Buy food, water, medicine, etc. as needed (either using the budget or money collected from fundraising) 	
Criticism from the other position (Person 1)	Where to send the supplies gathered? I think it will be difficult to properly distribute them to citizens without actually visiting the afflicted area. The Self-Defense Forces and firefighters will be stretched so thin at this time, I'm worried that they might not have time to respond to ordinary citizens. (The code of Phase I: asking and answering questions to clarify details of statements)	<ul style="list-style-type: none"> It will take a lot of time to go and investigate, then come back and gather people and then send them to the afflicted area. (The code of Phase II: identifying and stating areas of disagreement) In just three months from the earthquake, it seems like it would be difficult to conduct the lengthy processes of cleanup, research, and land development. (The code of Phase II: identifying and stating areas of disagreement) Because not all the people coming as volunteers are likely to have specific skills, it would be a waste if people who want to volunteer but who don't have skills or experience aren't allowed to do anything. (The code of Phase I: Asking and answering questions to clarify the details of statements) 	
Criticism from the other position (Person 2)	Regardless of past examples, in an unforeseen event, there's no way to know what kind of materials and other things will be scarce. Actually, going to the afflicted area and checking what's scarce and what's needed is the way to be sure. (The code of Phase II: identifying and stating areas of disagreement)	<ul style="list-style-type: none"> The preparatory investigation with just five people will take quite a long time, meaning that reconstruction and recovery will take longer. If a disaster occurs again during that time, it would be inefficient. (Phase II: identifying and stating areas of disagreement) We definitely should get hold of that kind of information, but this would be difficult without more specialized knowledge and tools. (The code of Phase II: identifying and stating areas of disagreement) 	II
Criticism from the other position (Person 3)	Food, water, medicine, etc. can be bought as needed, but it seems like there is no way to know what's needed without actually visiting the afflicted area. (The code of Phase II: identifying and stating areas of disagreement)	(Absent)	
Valuable aspects of the initial position following criticism	The only way to verify, understand, and provide support for the situation in the afflicted area is to go there. There's no way to know what solutions are possible otherwise. We don't just want to go and get superficial information, we also want to value communication with local people and engage with them appropriately. (The code of Phase II: restating participant's positions)	<ul style="list-style-type: none"> The absolutely necessary supplies and funds will not be available in the afflicted area, so they really should be collected from elsewhere. We think it will be possible to get information via TV and newspapers even outside the afflicted area, and professionals will be taking action immediately after the earthquake, so we should try and help them. It is also more efficient to have even one more person helping than just five people. (The code of Phase II: restating participant's positions) 	
Valuable aspects of both positions, that appear compatible	Before lots of people gather at places covered in the media, conduct an investigation being mindful of sending the right people for the task, and send the necessary number of people efficiently. (The code of Phase III: Identification of areas of agreement or overlap among the conflicting concepts)	Plan to improve efficiency by making the situation in the afflicted area clearer to everyone, communicating it to lots of people, recruiting more volunteer applicants, and increasing the number of people. (The code of Phase III: Identification of areas of agreement or overlap among the conflicting concepts)	III
Integrated idea	The five people will launch an official volunteer recruiting site that provides clear information on the situation in the afflicted area, asking applicants to fill out a simple questionnaire for quick analysis of their capacities. Volunteer dispatch locations will be allocated based thereupon, with those without special skills asked to do basic tasks, working towards reconstruction with large-scale cooperation. (The code of Phase III: Proposal and negotiation of new statements embodying compromise, co-construction)		

Table 4. Written content of a student’s ideas for supporting Position A in Group 3

	Content
Before PjBL	Provide donations. Raise awareness using social media. Raise the participation rate of junior and senior high school volunteer activities and increase their awareness. Set up partitions in the shelter to create private space. Deploy volunteers and hire cleaners to keep the shelter clean. Decide where to place people within the shelter according to the living environments and areas they are used to. Facilitate free Wi-Fi nationwide to allow immediate family contact even if something occurs. Make a list of the help needed in advance to send the right people to the right locations.
After PjBL	There is often a lack of information on evacuation in places with no signal, which can delay evacuation, thus making it difficult to confirm safety and avoid the spread of rumors. To prevent this, I believe that we need to first make sure that people have Internet access that can be used even if telephone poles have been destroyed, for example with portable chargers and pocket Wi-Fi. However, considering this measure alone would make people outside the affected area think it has nothing to do with them, thus putting a damper on donations and volunteers. Therefore, rather than providing free portable chargers, I think we should establish a system that allows people to receive information on the disaster area in certain conditions, such as once a day. Gathering on-site information elsewhere and sharing that information nationwide can enable a faster and more targeted recovery. To get people to follow the rules properly, we should tell them to stop using these resources if no information is provided.

However, they made it clear that they clung to their stance on support within the afflicted area. One of the influences of the teacher’s feedback within this activity was support for the students’ acceptance of criticism from the other group. Students received criticism based on the other group’s stance, and confirmed aspects of the initial idea that were lacking. Then, the impact of the criticism was increased via the teacher’s real-time color-coded feedback on the written criticism based on the other group’s stance.

A second influence was the color-coded feedback, which encouraged students to think more deeply. Using the color-coding, the teacher identified aspects that the students needed to examine further with respect to the criticism of the other group’s position. This encouraged

Table 5. Written content of a student’s ideas for supporting Position B in Group 3

	Content
Before PjBL	<ul style="list-style-type: none"> • Ensure privacy and safety in shelters • Maintain a clean living environment (shelters) • Share information from reliable organizations, make it accessible to all, and expand fund-raising activities • Support planning and opportunities for efficient recovery.
After PjBL	Instead of going to the disaster area, we will cooperate with people (organizations) who are already there, get information from them, and help spread the information to people elsewhere. It will not be possible to do this kind of work with only five people, and hence, we will work to increase the number of volunteers by providing information to people outside the disaster area. We will use the 10-million-yen budget to buy supplies to send to the disaster area and pay for our activities. We will decide in advance what sort of work we want volunteers to do. This aspect will enable volunteers to work more efficiently.

the students to think in a way that would lead to a greater attention to detail regarding support within the afflicted area and overcome the different approaches.

However, some students said that the color-coded feedback did not affect their stance at all, because they maintained their ideas throughout the discussion process, and there was a focus on critical responses to other groups.

4.2.2 Influence of Feedback in the Fourth Period

During the fourth period, the students began to generate new ideas by integrating the important aspects of the two positions. Doing so, the positive effects were identified from the use of color-coded keywords during the final idea stage, which encouraged thinking about how to realize their final ideas. The color-coded keywords enabled the students to perceive idea markers when integrating their thoughts and reflecting on important points from previous discussions.

The second influence, encouraging thinking about how to realize the final idea, arose from the teacher’s request highlighted in yellow for the students to be more specific about their key concerns. The students made these points more specific and restructured their ideas, leading to a final integration of positions.

Table 6. Interview analysis results on the influence of real-time color-coded teacher feedback

Third period: Relating to comments on problems viewed from both positions and reconfirmation of key points (Phase II)	
Positive influence	Supported student acceptance of criticism from the other group
	Using color-coded feedback encouraged the students to think more deeply
Reasons there was no influence	Retention of ideas through the discussion process
	Focus on critical responses to the other group
Fourth period: Relating to creation of ideas integrating the two positions (PhaseK III)	
Positive influence	Using color-coded keywords in the final idea stage
	Encouraged thinking about how to realize the final idea
Reasons there was no influence	No need to refer to color-coding because the key points were already clear
	No reference to color-coding because the ideas came first
	Lack of attention to color-coding because students were absorbed in the task
	Miscommunication between teacher and student due to color-coding

However, groups that had conducted discussions autonomously did not actively refer to the feedback, because there was no need to refer to the color-coding, and the key points were already clear. Furthermore, in groups that focused on how to construct new ideas to satisfy the key concerns of both positions, rather than integrating the key concerns need to construct ideas, the students did not refer to the color-coding. This is because the ideas came first. It was also found that in groups that did not have enough time to construct ideas, there was a lack of attention to the color-coding, because the students were absorbed in their task. Last, because the students had to describe their key concerns for support in the afflicted area in a limited space, there was some miscommunication between teacher and students.

5. Discussion

5.1 Effects of the Designed Model

This section discusses the effects of the PjBL with respect to the dissonance model designed in this study.

For design aspect 1, the control of the discussion process by setting a task having the same directionality in terms of its solution while including two conflicting positions was assessed from the evaluation results of Section 4.1, from which it was found that the criterion for Phase III was satisfied for nine out of nine (100%) integrated ideas. This indicates that the model was effective. However, only eight out of the nine (89%) final

integrated ideas satisfied the criterion for Phase II. Analysis of Table 3 confirmed the process by which dissonance initially emerged among students in relation to individual ideas based on what those students valued about their positions, after which those ideas were integrated. It was also confirmed that this discussion process influenced individual ideas, as shown in Tables 4 and 5. However, as can be observed from the examples in Table 3, some students' statements from the mutual critique did not reflect Phase II attainment at the individual level. Therefore, additional research is needed on the methods needed to improve quality.

For design aspect 2, using a synchronous system to provide real-time feedback from the teacher while controlling the discussion process, it appears that the real-time color-coded feedback from the teacher was effective for Phases I and II. However, the effects of this feedback method on the discussions during Phase III were limited for four possible reasons. First, because Phase III placed a high cognitive load on students, it disturbed their ability to address the color-coding. Second, the discussion may have developed in directions not originating from the teacher's color-coding. Third, until Phase II, the discussion had already been steered in a productive direction, and the students could autonomously develop their discussion. Fourth, the Google Sheets framework was not sufficient for the students to explain their key concerns for the support needed in the afflicted area. Hence, mutual understanding between the students and teachers was not achieved.

Therefore, the two core design aspects driving the model creation were found to facilitate effective support in Phases II and III and enabled the students to experience the social construction of knowledge by overcoming dissonance. It also appears that students were individually capable of proposing solutions to social issues that could overcome any dissonance.

5.2 Contributions to Research in Related Fields

This section summarizes the contributions of the present study to fields relating to PjBL intended to promote the social construction of knowledge in high schools using ICT. The first contribution is that by coding the discussions at each stage in terms of the idea, it was possible to examine the effects of the support in more detail than in previous studies. Specifically, as illustrated by the third period, this study identified that dissonance had increased in 89% of the ideas in Phase II. This aspect was achieved by dividing the students into conflicting positions, having the students create ideas based on this, and subsequently engaging the students in mutual criticism among those positions. This study also indicated that the social construction of knowledge had increased in 100% of the ideas in Phase III. This aspect was achieved by having the students rearticulate what they valued about both positions and then integrate their ideas based on that rearticulation.

The second contribution was to identify that it is possible to provide a method of facilitation for teachers enabled with a synchronous system. In previous studies, teachers have commented on statements written by students through online forums, but the effectiveness of using synchronous ICT to allow teachers to provide real-time feedback on discussion content had not been tested. The study results, however, confirmed the effect of real-time feedback by the teacher in terms of allowing students to discover and explore dissonance in Phase II. The present study was also able to partially confirm the effects of providing students with instructional scaffolding for the more difficult Phase III, i.e., the social construction of knowledge.

5.3 Practical Application in the Classroom

This study highlighted three issues for the practical application of PjBL in the classroom.

The first issue is related to the design of PjBL tasks. In the model presented in this study, the students began by envisioning the entities involved in resolving issues, and then listed the issues that were actually occurring. The model then recommended that a problem-solving task that was meaningful to the participants and had two contradictory positions [Position A and Position B (i.e., Position not A)] be selected. However, it is necessary that educators investigate issues that have conflicting positions in depth and make adjustments so that the class can be divided evenly in half. If the topic is expressed as a debate, this could better facilitate the development of contradictory positions; however, this framing could also make it difficult to set problem-solving tasks suitable for the PjBL. Therefore, future research should consider compiling case examples and focus on developing a more detailed task design process to improve the approach efficacy.

The second issue is related to the optimal perspective for monitoring the learner discussion process using real-time teacher feedback. This study presented criteria for feedback on good discussion processes and on those needing improvement. However, in practice, it is important for the teacher to subdivide the criteria for color-coding and consider the timing of the feedback based on the student characteristics and the situation at hand. Future research should also consider a study on experienced teachers to elucidate the points they address when using synchronous educational systems.

The third issue is related to integration of the ideas. As can be seen from the results of the interview survey, there were several ways to approach the development of integrated ideas. To ensure effective instruction and effective teacher feedback, more detailed research is needed on the process associated with generating integrated ideas.

6. Conclusion

In this study, the researchers designed and evaluated project-based learning (PjBL) to promote the social construction of knowledge by overcoming dissonance. The core aspects of the design were controlling the discussion process by setting a task with the same directionally in terms of its solution, while including two conflicting positions, and using a synchronous system to provide real-time feedback from the teacher and control the discussion process. Moreover, a four-part model was presented.

To evaluate the effects of this model, PjBL lessons were conducted with high school students. In these lessons, the topic was to consider ideas to support people living in shelters three months after an earthquake. The students reached Phase III in the discussions during class, and the real-time color-coded feedback from teachers was found to be effective in Phase II, but had a limited effect in Phase III.

Two major issues for future research were found. The first, based on the points from this present study, is related to the need for more detailed analyses of the task-setting process, the teachers' perspective of the real-time feedback, and the process associated with the integration of ideas. The second issue was related to a project-based learning model design that integrates Phases IV–V.

Authors' note

Although the aim of this study is the same as the study conducted by [20], it differs from the latter in that it refines the design and evaluation methods.

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