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Experiences and Views on Interdisciplinary Project-based Learning Program for Teachers and Students

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Abstract

This two-year study investigated the impact of professional development interventions for teachers on students' learning. In the first year, this study focused on designing, implementing, and evaluating the teachers' professional development program of interdisciplinary project-based Learning (T-IPjBLP). In the second year, this study focused on the experimental teaching of the student learning program of interdisciplinary project-based learning (S-IPjBLP) that teachers designed. Further, the author assessed the impact of S-IPjBLP on students' capacities for critical thinking, communication, creativity, and collaboration (i.e., the 4Cs) and technological application from teachers' and students' views. The participants comprised seven teachers who taught natural science and technology subjects at the same junior high school in central Taiwan and their 26 eighth-graders. The results revealed that after attending the T-IPjBLP, the teachers' beliefs changed from a teacher-centered approach to a learner-centered approach, and their knowledge of PjBL improved significantly. After implementing the S-IPjBLP in class, teachers affirmed that PjBL pedagogy was a practical approach for increasing the students' 4Cs capacities and technological application. The barriers that they encountered included time constraints and mandated curriculum pacing. Regarding student learning, students had positive experiences and feelings toward the S-IPjBLP. Most perceived that S-IPjBLP could improve their capacities for 4Cs and technological applications.

Keywords: teacher professional program, interdisciplinary project-based learning, student learning, program evaluation, 21st-century capacities

1. Introduction

With the rapid progress in science and technology, the world has become increasingly digital and very different from what we experienced in the 20th Century. Cultivating students' ability to cope with a rapidly changing environment has become an important issue at all school levels. In recent years, countries worldwide have successively proposed a framework of core literacy or critical competencies for the 21st Century, among which the capacities for critical thinking, creativity, communication, collaboration, and application of technology have become increasingly important (Harper, 2014).

Kokotsaki et al. (2016) claimed that traditional teacher-centered pedagogy can no longer meet future education needs and cannot effectively teach students the essential skills needed for the 21st Century (Harper, 2014). Ravitz et al. (2012) found that project-based learning (PjBL) is the most commonly used and effective method for teaching students essential 21st-century skills. PjBL is an innovative and comprehensive learning orientation that connects students, courses, real-world issues, and communities through a project inquiry process of student collaboration (Bell, 2010; Bransford & Stein, 1993). Through PjBL, students actively think, plan, discuss agendas, divide labor, and cooperate; complete tasks, propose problem-solving strategies, reflect, and create knowledge; and become proficient in communication, problem-solving, and diversity management. The teacher is a facilitator rather than a director (Brown & Campione, 1994; Han & Bhattacharya, 2001; Harper, 2014). Many studies indicated that PjBL could develop students' 21st-century skills and bring unlimited benefits to their future work and lives (Bell, 2010; Larmer, 2020; Larmer & Mergendoller, 2012).

Many empirical studies have confirmed that PjBL integrates a variety of learning areas through inquiry into real-world issues to help students acquire more profound knowledge and skills and enable them to develop from novices to experts in their field of knowledge and demonstrate the ability to learn in their fields of works (Grant & Branch, 2005; Tamim & Grant, 2013). PjBL can also trigger students' intrinsic motivation to learn, allowing each student to experience success. PjBL can also help students master creativity and innovation, communication, critical thinking, and collaboration skills (Budiarti et al., 2021; Haniah et al., 2021; Tamim & Grant, 2013). PjBL is also an effective teaching strategy for students with no motivation and low achievement (Mergendoller et al., 2003).

Teacher professional development is the primary mechanism for improving classroom teaching and enhancing student learning effectiveness (Ball & Cohen, 1999; Cohen & Hill, 2000). However, this connection needs to be identified in how teacher professional development affects student achievement. According to Yoon et al. (2007), the link between teacher professional development and student achievement derives from the following steps: (1) teachers improve their knowledge, skills, and motivation through professional development pathways; (2) teachers apply the knowledge and skills acquired in professional development to classroom teaching; and (3) teachers improve their teaching, thus raising student achievement. If one link is weak or missing, better student learning cannot be expected. In other words, teachers' teaching beliefs and pedagogy must be changed if one

wants to develop students' core competencies effectively in the 21st Century. Therefore, the West Virginia Department of Education conducted a pioneering study in 2008, using PjBL as the central axis of teachers' professional development. The study allowed teachers to inquire about PjBL curriculum design, learning assessment, classroom observation, and teaching reflection. Further, to evaluate the effectiveness of their professional development. The study findings showed that teachers who had a deeper understanding of PjBL pedagogy could demonstrate more diverse strategies in classroom teaching and apply multiple approaches to measure students' core competencies for the 21st Century (Ravitz, 2008).

In response to the future development of the 21st Century, Taiwan has promoted the 12-year reform of national primary education. However, under exam-led teaching in Taiwan, most teachers have adopted the traditional teacher-centered pedagogy for a long time. In traditional teacher-centered pedagogy, the teacher spends most of the class time presenting lectures, and students seldom can conduct peer inquiry together. An instructor explains concepts, presents analogies, provides answers, and may demonstrate step-by-step procedures for solving various exercises. Although this can be an efficient way to present information, there needs to be a learning environment where students learn effectively and develop critical skills for the future (Ministry of Education, Taiwan, 2013).

Natural sciences have always been a critical field of study in Taiwan's middle school stage, which aims to cultivate students' interest in exploring science, develop a habit of active learning and the ability to communicate, promote working in teams and living in harmony with other people; encourage students to think independently, solve problems, and stimulate their potential; and enable students to perceive and test the interaction between people and technology (Ministry of Education, Taiwan, 2013). However, in Taiwan, PjBL pedagogy is rarely applied to teaching natural sciences and technology in junior high schools because teachers tend to teach natural sciences using traditional pedagogy to prepare them for entrance examinations.

Therefore, this study recruited Natural Sciences teachers of one junior high school who attended the T-IPjBLP for professional development and designed students' Interdisciplinary Project-based Learning Program (S-IPjBLP) for experimental teaching. The research questions of this study included: (1) Did the teachers change their beliefs and gain PjBL knowledge and skills? (2) what was the teacher's opinion of IPjBL pedagogy after the experimental teaching? (3) What were the experiences, feelings, and impacts the students perceived about the S-IPjBLP?

2. Methodology

2.1 Program participants

In the first year, the participants comprised seven teachers (four females and three males) who taught subjects in natural sciences and technology; their teaching seniorities were between 10 and 29 years. All of these seven teachers participated in the T-IPjBLP professional growth workshops and jointly designed an experimental program (S-IPjBLP) for

eighth graders. In the second year, one of them who was a volunteer served as the instructor for the experimental teaching, while the others served as the classroom teaching observers. Twenty-six eighth-grade students participated in the S-IMPjBLP.

2.2 The descriptions of T-IPjBLP and workshops

The T-IPjBLP comes from experiential learning theory and social constructivism theory and comprises four elements: concept construction, experiential learning, program development, and experimental teaching. The program activities are conducted mainly through school-based professional learning community (PLC) models, including self-guided learning, professional dialogue, topic lectures, experience sharing, case studies, development plans, and tentative experimental teaching. As shown in Table1, T-IPjBLP consisted of 12 topics. Each topic lasted different hours, from three to thirty.

Each workshop lasted three hours.

Table 1. The T-IPjBLP Workshops

Focus	Topic	Hour
Concept construction	1.Core Competencies of The 21st Century And Future Education	tree
	2.Teachers' Roles and Responsibilities in The 21st Century	three
	3. The Connection between PjBL and Core Competencies of The 21st Century	three
	4. Core Concepts Of PjBL	six
	5. Elements of PjBL Curriculum Design and Implementation	six
	6. Pjbl Implementation and Influencing Factors	six
	7. The PjBL Case Study	six
Experimental learning	8. Experience The Process Of PjBL	six
	9. Present The Results of Experimental Learning	three
Program development	10. Design One PjBL Unit	three
	11. Tentative Teaching and Professional Dialogue	six
	12. Develop the S-PjBLP	thirty

2.3 The description of S-IPjBLP

The instruction steps of S-IPjBLP consisted of the follows:

1. Through the entry event, teachers stimulate students' curiosity, interest, and learning needs so that they can think about interesting topics for the project-inquiry.

2. In the processes of the project inquiry, each group of students assigns tasks, sets goals and progress, learns to use time effectively, and monitors their progress. Teachers need to check that students are developing their concepts and skills on the research track.

3. The project resources required by each group include documents, computers, scientific detectors, compasses, CDs, and advice from external experts.

4. Students bridge the gap between knowledge and skills through scaffolding assistance to achieve their learning tasks.

5. In the process of the project inquiry, students work collaboratively on the task for which they are responsible and complete the final work. The groups may review each other's research results and provide feedback.

6. The inquiry conducted during S-IPjBLP is on a real-world issue; students actively gather information, generate discoveries, and deduce conclusions. Teachers must foster a class culture that values questioning, assumptions, and openness to new ideas and horizons and encourage students to share insights into topics.

7. In the processes of IPjBL, teachers should regularly provide opportunities for students to reflect. In addition to providing real-time feedback, students should be trained to use standards or other criteria to evaluate each other's work. Alternatively, teachers should arrange for experts to provide feedback and revisions to students' work.

8. By presenting their results to classmates, teachers, and authentic audiences outside of the school instead of receiving teachers' inspection or grading, students will pay greater attention to the quality of the inquiry results and experience more meaningful learning.

The S-IPjBLP aims to enhance the students' capacities for critical thinking, communication, creativity, collaboration, and technological application.

2.4 Data Collection for Teacher Learning

2.4.1 Teachers' Belief Scale

This study used the Teachers' Belief Scale as a pre-test and post-test tool to measure the teachers' beliefs. The scale consists of three subscales: curriculum design, instruction and assessment, and student learning. Each subscale is divided into traditional and open approaches. The former leans toward restrictive, conservative, teacher-centered, normative arguments, while the latter adopts liberal, open, student-centered, development-oriented arguments. The teachers responded to the items on a five-point Likert scale ranging from 1 (strong disagreement) to 5 (strong agreement).

2.4.2 Cognitive test of PjBL

The study developed a PjBL cognitive test for teachers as a pre-test and post-test tool consisting of four sections: theory sources, curriculum design, teaching activity, and learning assessment. The more questions the teacher answered correctly, the higher the scores, indicating that the teacher better understood PjBL. The scores for each section ranged from 0 to 100. The test questions were selected from lecture notes, articles, and videos provided by the workshop.

2.4.3 E-portfolio of professional development

During the implementation of the T-IPjBLP, participants were asked to make an e-portfolio of professional growth, sharing their program experience, professional knowledge, skills, and attitudes learned from the program to facilitate mutual sharing, exchange, and learning.

2.4.4 Individual interview

At the end of the experimental teaching, the participants were individually interviewed with the following questions: “What are their views on the T-IPjBLP?” “What are their views on the limitations of its implementation of S-IPjBLP?”

2.5 Data collection for student learning

2.5.1 Feedback sheet

During the experimental teaching period, students were required to complete feedback sheets addressed their program experiences, feelings and impacts.

2.5.2 Focus group interview

To understand the students' perceptions of the impact of S-IPjBLP, 10 of the 49 students were invited to participate in the focus group interviews, where they could share their program experiences, feelings and impacts.

3. Results

3.1 Teacher Professional Development

3.1.1 Teachers’ Teaching Belief Changes

This study used the Teachers’ Belief Scale to assess changes in teachers’ teaching beliefs. The results of the paired t-test analysis shown in Table 2 indicated that teachers’ post-test scores in the learner-centered approach (LC) subscales of curriculum design, instruction and assessment, and student learning were higher than their pre-test scores. Teachers’ post-test scores in the teacher-centered (TC) approach subscales of curriculum design, instruction and assessment, and student learning were lower than their pre-test scores. This finding showed that after participating in various types of professional growth activities, the teachers’ beliefs tended to be closer to an LC approach, which is an open, student-centered, development-oriented viewpoint in line with the educational philosophy of PjBL.

Table 2. Results of the Paired T-Test for Teachers to Measure Teaching Beliefs

		Pre-test		*Post-test*	
Subscale	Approach	*M*	*SD*	*M*	*SD*
Curriculum design	TC	4.54	1.01	2.57	0.92
	LC	2.25	0.89	4.46	1.00
Instruction & assessment	TC	4.86	0.82	2.29	0.82
	LC	1.96	0.76	4.64	0.92
Student learning	TC	5.00	0.89	2.14	0.65
	LC	2.00	0.70	4.95	0.82

In addition to the scale assessment, the teachers shared their views on the PjBL pedagogy, which can be used as evidence of the changes in their teaching beliefs based on the T-IPjBLP, as summarized below.

The most important thing I learned from the T-IPjBLP is that teachers should not be afraid of change and should constantly reflect on their teaching beliefs and practices. PjBL pedagogy is closer to students' life experiences and meets their needs better than traditional pedagogy. (E-portfolio TA)

I was very impressed by the PjBL teaching strategy shared in the lectures. I tried to use it in my class and found that the outcomes were good, and I felt that my teaching level improved. (E-portfolio TC)

I learned an alternative mindset in instructional design from the program and benefited from the experience of learning through collaborative learning. It is effective in constructing knowledge. (E-portfolio TE)

The most impressive part of the program is that the lecturers design great questions that trigger and guide us to engage in discussions. These questions helped me think about how to improve my curriculum design. (E-portfolio TF)

Most impressive is the grouping process in the curriculum design workshop. Collaborative learning activities are vital because they are critical in promoting peer dialogue. (E-portfolio TG)

3.1.2 Teachers' Knowledge Change

This study used the Teachers' Belief Scale as a pre-test and post-test tool to measure the teachers' beliefs. The scale consists of three subscales: curriculum design, instruction and assessment, and student learning. Each subscale is divided into traditional and open approaches. The former leans toward restrictive, conservative, teacher-centered, normative arguments, while the latter adopts liberal, open, student-centered, development-oriented arguments. The teachers responded to the items on a five-point Likert scale ranging from 1 (strong disagreement) to 5 (strong agreement). Figure 1 shows that the teachers increased their knowledge of PjBL after attending various professional growth activities.

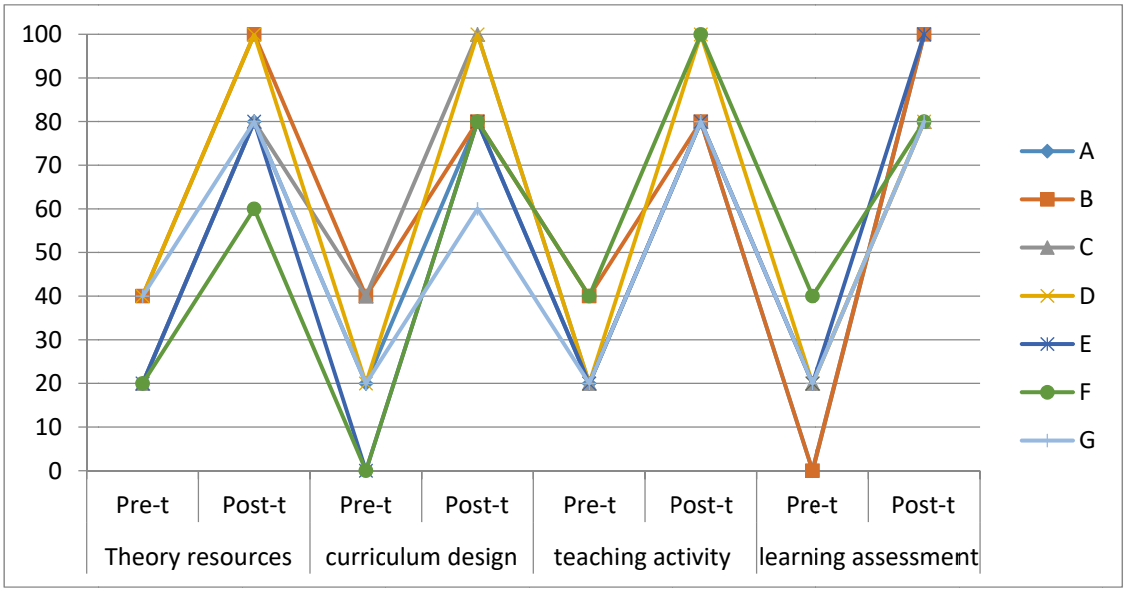

Fig. 1. Comparison between pre-test and post-test of teachers' cognitive test scores.

The participants also shared the concepts that they learned from the program in their E-portfolios, as summarized below:

IPjBL is an innovative teaching approach that fosters communication and problem-solving proficiency, from which students gain many life-related skills. (E-portfolio TA)

IPjBL is a learning style in which students ask inquiry questions and conduct research under the teacher's supervision. Students can learn communication, negotiation, and collaboration capacities from the inquiry processes. (E-portfolio TB)

IPjBL is a teaching method that teaches the core concepts of a curriculum through a particular topic. The project focuses on a question of inquiry, allowing students to apply what they have learned from the curricula. (E-portfolio TC)

The assessment of IPjBL is authentic, including self-evaluation and reflection. Students self-assess the level of their projects, efforts, motivations, interests, and research findings. They improve the quality of their projects by providing constructive feedback to each other. (E-portfolio TD)

IPjBL focuses on topics that provoke students to explore, allowing them to participate and construct knowledge to solve problems related to real-world situations. However, when teachers choose to use PjBL in the classroom, they may face particular challenges, such as classroom discipline issues. (E-portfolio TE)

IPjBL is a teaching and learning strategy involving learners in solving complex problems in which they research, synthesize information, and learn various abilities. (E-portfolio TF)

There are many challenges for teachers. For example, teachers need to be skilled in taking a student-centered approach. They need to be motivated and able to adopt new teaching strategies. They need to have the confidence to manage IPjBL activities. Teachers need to be able to overcome these challenges to implement PjBL successfully. (E-portfolio TG)

3.2 Teachers' Views on the S-IPjBLP After Implementation

The teachers shared in the interviews that the S-IPjBLP has the following advantages: through practice, it can trigger the motivation of low-achieving students to participate in the classroom; through problem solving, students can cultivate the ability to think critically and create; through the search for information and the production of results, students can enhance their ability to apply technology; through the process of inquiry, students can actively construct knowledge and cultivate their ability to learn independently. These ideas were obtained from the following excerpts:

S-IPjBLP is a student-focused learning model. With the assistance of teachers, students plan, implement, and self-evaluate their learning to become significant learning roles. (Interview TE)

The most significant difference from traditional teaching is that S-IPjBLP gives students more waiting time and interactive questions, translating scientific concepts into practical applications. (Interview TG)

S-IPjBLP guides students to think about what they have learned and apply it to their lives. (Interview TB)

S-IPjBLP develops students' communication and cooperation skills and encourages them to explore and solve real-life problems. (Interview TF)

Low-achieving children have never been motivated to learn during class, but group project inquiries engage them in learning. That is much progress for them. (Interview TE)

Each group of students must focus on the problem and think about what solutions are available through brainstorming during the process of project inquiry. It can invisibly cultivate students' critical thinking. (Interview TD)

Students have to cooperate with their classmates to rethink what they have learned and make the knowledge they have learned more understood during the process of project inquiry. (Interview TA)

During project inquiry, students must apply technology to find information and present project outcomes. From the presentation of the results, we can see the students' ability to apply science and technology. (Interview TB)

During project inquiry, students construct knowledge autonomously to learn how to learn and cultivate their self-learning spirit. (Interview TC)

However, the respondents said that barriers to implementing S-IPjBLP are time constraints and mandated curriculum pacing.

S-IPjBLP requires more time on the project inquiry to complete the unit. (Interview TA)

S-IPjBLP takes more teaching time. Teaching natural science in junior high school entails the pressure of teaching progress and grades, and insufficient time is the most significant

limitation. (Interview TB)

For teachers, S-IPjBLP is not only innovative but also challenging. During project inquiry, students have to spend much time on discussion, data collection, technology usage, results presentation, etc. There needs to be more class time. (Interview TC)

3.3 Students' Experiences of and Feelings about the S-IPjBLP

Most students said that the pedagogy of S-MPjBLP differed from before. In the past, the teacher had been more focused on concept demonstrations and exercises, and there was less interaction between peers. There was more interaction between the teacher and the classmates. The S-MPjBLP adopted heterogeneous grouping and task assignment, and the group leader would regularly monitor the progress and report back to the teacher. During a project inquiry, the teacher would tour the groups, give appropriate assistance and guidance, and prompt students by asking questions to explore the factors or principles behind the phenomenon. The students in each group completed the task together through communication, collaboration, critical thinking, innovative thinking, and the application of technology. At the end of the inquiry, each group publicly presented the results of the projects.

S1: This semester, the teacher's class was not the same as last semester; at the beginning of the group, the students interacted more; everyone had a task to complete. The group leader must report on the progress to the teacher. If I did not know, I would ask my classmates, and they were very willing to help me.

S4: I dozed off less this semester because the teacher would check each group's progress and discuss it with my classmates, and I couldn't talk to my classmates in class before, so I wanted to sleep.

S5: I often will not answer the question asked by the teacher, but the students in my group give me hints to let me know the answer.

S15: The teachers often asked us why and asked us to think about what caused it.

S26: After completing the project inquiry, each group will display the product in the exhibition room for everyone to see.

(Focus group interview)

When asked about the S-IPjBLP, the students said they liked this way of attending classes, felt more valued by the teacher, and had a sense of participation. They felt that a hands-on working style could deepen the learning content, and they were pleased to interact with classmates and express their views. This type of teaching also enhanced feelings between peers, and they found it very rewarding to show the results of the project inquiry. The following excerpts show the students' words:

S3: I feel more valued by the teacher and more involved in the class this semester because I can express my opinion.

S4: I did not understand what the teacher said in class before, so I gave up learning. However,

this semester I became different. I was involved more in the class now.

S25: I enjoyed interacting with my classmates and participating in discussions. You can express your opinions and speak, and your willingness to attend classes is relatively high.

S23: The opportunity to interact with classmates has increased dramatically, and the willingness to learn is much higher!

S20: I can interact with my classmates and love that feeling.

S19: Before the work is presented, we must discuss it before deciding on how to do it, and we have a great sense of accomplishment after completion.

(Focus group interview)

3.4 Students perceived the program's impact on themselves

3.4.1 Increasing their abilities of critical thinking skills

Observing the film, listening to others' opinions, thinking about problems from different angles, and completing the projects can improve students' critical thinking skills:

Flute making in the course has enhanced my critical thinking skills because I found that wet cotton will make a sound when stuffed into a straw. (feedback S15)

Thinking about problems from different angles has enhanced my critical thinking ability. (feedback S13)

Watching videos in the course because I can guess different answers has improved my critical thinking skills. (feedback S6)

3.4.2 Increasing their abilities of technological application

Students tune through mobile apps and try to make musical instruments using different materials, shadow games, online homework, editing videos, etc., which can trigger innovative thinking and enhance their ability to apply technology.

I can use my phone app to tune the sound, which I never thought of before (feedback S2)。

In the process of making my instruments, I try different materials to get different results, which increases my creative thinking (feedback S18)

Making my musical instruments is very interesting, and the process of making my instruments enhances my creative thinking (feedback S24)

Shadow games enhance my creative thinking because it will make people more imaginative (feedback S11)

Making a video enhance my ability for technological application. (feedback S8)

3.4.3 Increasing their abilities of communication

Students perceived the inquiry process that taking the initiative to ask questions, communicating with peers, cooperating, and completing tasks together can enhance their

communication and collaboration skills.

During the inquiry, I try to understand what people are saying and understand, so I think my communication skills have improved (feedback S9)

During the inquiry, I need to complete tasks together. While I do not understand, I must ask classmates, so my communication skills have improved. (feedback S12)

In the inquiry process, we have to finish the project together, which can enhance my cooperation ability. (feedback S16)

4. Discussion

Professional development in education is defined as the processes and activities designed to enhance educators' professional knowledge, skills, and attitudes so that they might, in turn, improve the learning of students (Guskey, 2009). Teachers highly value professional development that connects teacher and student perspectives and provides foundational knowledge about how students learn and think about science. Even though educators have many opportunities for professional development. However, relatively little systematic research has been conducted on the relationship between professional development and teacher and student learning (Buczynski & Hansen, 2010; Garet et al., 2001).

In this study, the author investigated the impact of professional development interventions for teachers on students' learning from teachers' and students' views. The result indicated that after participating in the T-IPjBLP, teachers changed their teaching beliefs and acquired new knowledge and skills. Moreover, teachers develop a new program, plan strategies to improve instruction, and further enhance students' capacities for 4Cs and technological applications.

In this study, after implementing the S-IPjBLP, teachers affirmed that the PjBL approach is practical for increasing students' 4Cs and technological application competencies. The findings of this study are consistent with the results of many studies (e.g., Bell, 2010; Buck Institute for Education, 2013; Kokotsaki et al., 2016). This finding may be because IPjBL breaks through traditional teacher-centered approaches that have standard Q&A. In addition, IPjBL emphasizes students as the main focus and respect for individual differences. In the inquiry process, communication, criticism, collaboration, innovation, and scientific and technological application were emphasized so every student could actively participate in learning. Moving from learning isolation to becoming a group member and learning with peers enhanced their sense of belonging. PjBL provided more clues and opportunities for learning, which increased their motivation to learn and participate in the classroom.

However, in this study, teachers encountered some barriers—especially time constraints and mandated curriculum pacing. These findings are consistent with the findings of Viro et al. (2020). As Fishman et al. (2003) said, IPjBL is an inquiry-oriented approach to teaching and learning. This approach is widely recognized as demanding because it involves changes in classroom management strategies, the organization of knowledge, and assessment. This approach challenged the teachers' existing capabilities in this study. However, these challenges will likely diminish as the teachers now have a deeper understanding of PjBL

pedagogy and mastery of experimental processes.

Regarding students' views on experiences of S-IPjBLP, the findings showed that students had positive experiences and feelings toward the S-IPjBLP. This finding was consistent with many other studies confirming that the IPjBL approach triggers students' motivation to learn, creates a positive attitude toward learning, increases classroom engagement and collaboration, develops positive emotions, and enables successful experiences (Duman & Yavuz, 2018; Katz & Chard, 1992; Larmer & Mergendoller, 2012, 2015; Markham et al., 2003; Wolk, 1994). Some possible reasons for these benefits may be that, in the MPjBL classroom, an instructor establishes a supportive environment that allows students to present their ideas without hesitation or fear. During the inquiry process, teachers functioned as facilitators, from the idea of the topic to the presentation of the results, and fully respected the students' opinions. Hence, students had positive experiences and feelings toward the S-MPjBLP.

Another finding from teachers' and students' views showed that the S-IPjBLP positively affected students' 4Cs and technological application capacities. This finding is similar to several previous studies (Budiarti et al., 2021; Haniah et al., 2021; Tamim & Grant, 2013). A possible reason is that IPjBL gives students more opportunities to explore, think about, and transform the scientific concepts of understanding into practical experiences through peer communication and collaboration. Teachers provided students with opportunities for self-decision-making and innovation and provided feedback mechanisms to assist students in making thoughtful decisions, revisions, and innovative works. In the inquiry process, students were also asked to use scientific and technological tools and information systems to surf the web, collect data, and present their project results.

Teacher professional development is the primary mechanism for improving classroom teaching and enhancing student learning effectiveness (Ball & Cohen, 1999; Cohen & Hill, 2000). this study linked between teacher professional development and student learning and like previous studies conducted in different countries, confirmed that IPjBL and inquiry-based teaching methods provided opportunities for students to master 21st-century capacities, such as the 4Cs and technological application capacities.

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References

Bell, S. (2010). Project-based learning for the 21st century: Skills for the future. *The Clearing House, 83,* 39-43. https://doi.org/10.1080/00098650903505415

Bender, W. N. (2012). Project-based learning: Differentiating instruction for the 21st Century. Corwin.

Borko, H., Jacobs, J., & Koellner, K. (2010). Contemporary approaches to teacher professional development. In P. Peterson, E. Baker, & B. McGaw (Eds), *International Encyclopedia of Education, 7,* 548-556.

https://doi.org/10.1016/B978-0-08-044894-7.00654-0

Buck Institute for Education. (2013). Research summary: PjBL and 21st century competencies.
http://pblworks.org/sites/default/files/2019-01/FreeBIE_Research_Summary.pdf

Buczynski, S., & Hansen, C. B. (2010). Impact of Professional Development on Teacher Practice: Uncovering Connections. *Teaching and Teacher Education, 26,* 599-607. https://doi.org/10.1016/j.tate.2009.09.006

Budiarti, M., Macqueen, S., Ferguson-Patrick, K., & Reynolds, R. (2021). Global project-based learning as an approach to teaching the 4cs in schools. *Journal of International Social Studies, 11*(1), 33-62.

Centre for Education in Science & Technology (2022). Importance of technology in schools. https://www.cest.org.uk/

Cohen, D. K., & Hill, H. (2000). Instructional policy and classroom performance: The mathematics reform in California. *The Teachers College Record, 102,* 294-343. https://doi.org/10.1111/0161-4681.00057

Dewey, J. (1938). *Experience and education.* Simon and Schuster.

Duman, B., & Yavuz, Ö. K. (2018). The effect of project-based learning on students' attitude towards English classes. *Journal of Education and Training Studies, 6*(11), 86-193. https://doi.org/10.11114/jets.v6i11a.3816

Fishman, B. J., Marx, R. W., Best, S., & Tal, R. (2003). Linking teacher and student learning to improve professional development in systemic reform. *Teaching and Teacher Education, 19*(6), 643-658. https://doi.org/10.1016/S0742-051X(03)00059-3

Grant, M. M. & Branch, R. M. (2005). Project-based learning in a middle school: Tracing abilities through the artifacts of learning. *Journal of Research on Technology in Education, 38*(1), 65-98. https://doi.org/10.1080/15391523.2005.10782450

Guskey, T. R. (2009). Closing the knowledge gap on effective professional development. *Educational Horizons, 87*(4), 224-233.

Haniah, A. U., Ngadiso, N., & Setyaningsih, E. (2021). Students' perception on the implementation of online project-based learning in teaching 4cs. *Indonesian Journal of English Language Teaching and Applied Linguistics, 6*(1), 123-140. https://doi.org/10.21093/ijeltal.v6i1.895

Harper, A. (2014). Teacher guide: Using project-based learning to develop students' key competences.
http://keyconet.eun.org/c/document_library/get_file?uuid=d2e33016-9c19-4901-aa00-5d25c5d734f2&groupId=11028

Johnson, B. (2019). January 16). 4 Ways to Develop Creativity in Students. https://www.edutopia.org/article/4-ways-develop-creativity-students

Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). P*roject-based learning: A review of the literature. Improving schools, 19*(3), 267-277. https://doi.org/10.1177/1365480216659733

Larmer, J., & Mergendoller, J. (2015). Why We Changed Our Model of the "8 Essential

Elements of PBL". Buck Institute for Education.

Larmer, J. (2020, July 22). Gold Standard PBL: Essential Project Design Elements. http://bie.org/blog/gold_standard_pbl_essential_project_design_elements

Larmer, J., & Mergendoller, J. R. (2012). 7 Essentials for Project-Based Learning. https://static1.squarespace.com/static/530e32e2e4b02e9cbe11317b/t/54b044c9e4b0265c9838432f/1420838089897/8+PBL+Essentials.pdf

Markham, T., Larmer, J., & Ravitz, J. (2003). Project-based learning handbook: A guide to standards focused project-based learning for middle and high school teachers. Buck Institute for Education.

Ministry of Education (2014). Guideline of the twelve-year national basic education curriculum. Taipei City: Author.

Ravitz, J., Hixson, N., English, M., & Mergendoller, J. (2012, April). Using project-based learning to teach 21st century skills: Findings from a statewide initiative. Paper presented at Annual Meetings of the American Educational Research Association. Vancouver, BC.

Supovitz, J. A. & Turner, H.M. (2000). The effects of professional development on science teaching practices and classroom culture. *Journal of Research in Science Teaching, 37*(9), 963-980. https://doi.org/10.1002/1098-2736(200011)37:9<963::AID-TEA6>3.0.CO;2-0

Tamim, S. R., & Grant, M. M. (2013). Definitions and uses: Case study of teachers implementing project-based learning. *Interdisciplinary Journal of Problem-Based Learning, 7*(2), 72-101. https://doi.org/10.7771/1541-5015.1323

Viro, E., Lehtonen, D., Joutsenlahti, J., & Tahvanainen, V. (2020). Teachers' perspectives on project-based learning in mathematics and science. *European Journal of Science and Mathematics Education, 8*(1), 12-31. https://doi.org/10.30935/scimath/9544

Vygotsky, L. S. (1978). Mind in society: The development of higher psychological processes. Harvard University Press.

Yoon, K. S., Duncan, T., Lee, S. Wen-Yu, Scarloss, B., & Shapley, K. L. (2007). Reviewing the evidence on how teacher professional development affects student achievement (ED498548). ERIC. https://files.eric.ed.gov/fulltext/ED498548.pdf

Zhu, Y. -Y & Ye, Y. -H. (2001). Teacher Belief Scale. http://www3.nccu.edu.tw/~ycyeh/instrument-english/2001%20teacher%20belief.pdf