A Fundamental Examination of the Determinants of Inquiry-based Learning Attitudes Across Subject Differences between Mathematics and Other Subjects

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Abstract: *Inquiry-based learning (IBL) is widely regarded as a key pedagogical approach for fostering 21st-century skills. However, the extent to which subject specialization and ICT competencies shape teachers' attitudes and implementation of IBL remain unclear. This study surveyed 611 elementary, middle, and high school teachers in Japan, categorized into mathematics and non-mathematics groups. We examined three dimensions of IBL attitudes (perceptions, instructional confidence, and perceived importance), four ICT skill factors (lesson preparation, in-class use, student guidance, and ICT ethics), years of IBL instruction, and overall teaching experience. Welch's t-tests revealed no significant differences between the two groups in IBL attitudes or ICT competencies. Multiple regression analysis showed that classroom-oriented ICT skills (in-class use, student guidance) and prior experience in IBL were significant positive predictors of IBL attitudes. In contrast, lesson preparation skills were negatively associated with confidence and perceived importance. These findings suggest that real-time, student-centered ICT integration and hands-on IBL experience play a more critical role than subject expertise in shaping teachers' readiness and receptiveness to implement IBL. Implications for professional development are discussed.*

1. Introduction

1.1. Research Background

In recent years, with the advancement of globalization and advanced information technology, the cultivation of 21st-century skills such as creativity and problem-solving ability has become the most important issue in education [1]. Inquiry-based learning (IBL) has been recognized as an effective approach for fostering these skills. IBL has been reported to comprehensively cultivate various skills, including information literacy, communication skills, and metacognitive abilities, through the process of students posing questions, collecting and analyzing information, and constructing conclusions [2]. Additionally, in an advanced information society, the cultivation of creative and innovative human resources is increasingly emphasized, and IBL is expected to serve as a key educational practice in this regard [3].

On the other hand, differences in the penetration of IBL practices and teachers' acceptance of them have been pointed out depending on the subject and field. A systematic review of IBL models by Pedaste et al. [4] showed that the introduction of inquiry-based approaches in mathematics education is relatively slower than in science education. Besides, Minner et al. [5] reported on the effects of inquiry-based instruction in science education in a meta-analysis. Additionally, Anderson [6] revealed in a review of science teacher education research that positive attitudes toward "student-generated questions" were more strongly dependent on individual educational beliefs than on specialized fields. Furthermore, a teacher practice survey by Windschitl et al. [7] showed that teachers' understanding of and willingness to apply core elements of IBL practices common across subjects were based on their views on inquiry education rather than their subject expertise. This suggests that both teachers' subject expertise and their views and attitudes toward IBL may influence the implementation of IBL.

As empirical research in Japan, Sano et al. [8] surveyed elementary, junior high, and high school teachers on their perceptions of IBL, its importance, and their confidence in teaching it, and reported no significant differences between school types. Rather, teachers with a test-oriented teaching philosophy had a lower recognition of the importance of IBL, while teachers who emphasized "basic concept mastery," "student autonomy and individualization," and "development of subject-specific abilities" were more positive toward IBL.

IBL is not a learning method that seeks predetermined answers; therefore, learners need to actively explore unknown problems through continuous learning. To enhance this process, the accumulation of digital portfolios using ICT is effective. In fact, Barrett [9] showed that learners' metacognitive monitoring abilities improved by repeatedly recording their learning in electronic portfolios and conducting self-assessments. Furthermore, online information sharing among learners promotes the exchange of different perspectives and collaborative problem solving, leading to deeper learning. Hew and Brush [10] reported that ICT-supported collaborative learning inside and outside the classroom contributes to improving learning outcomes. In addition, by utilizing tools for visualizing thought processes (such as mind maps and graphic organizers), learners can visually confirm their own hypothesis formulation and verification processes and clarify their problem-solving strategies. Voogt and Pareja Roblin [11] argue that the use of ICT forms the basis for collaborative and creative inquiry activities in the development of 21st-century skills. Based on these previous studies, the accumulation of ICT-based portfolios, information sharing among learners, and the visualization of thinking processes play an important role in enhancing the quality of IBL. The Japanese Ministry of Education, Culture, Sports, Science and Technology [12] classifies the ICT utilization skills required of teachers into four categories: 1:Utilization of ICT in teaching material research and lesson preparation, 2: Utilization of ICT during lessons, 3: Utilization of ICT in student guidance, and 4: Information ethics guidance. With the promotion of the GIGA School Project in Japan, which aims to provide one device per student, improving these ICT skills has become an important research topic in terms of its impact on the qualitative improvement of IBL.

Regarding the relationship between attitudes toward IBL and ICT skills, Fukui et al. [13] conducted a survey in Japan and found that teachers with higher ICT skills had significantly higher understanding and implementation rates of IBL, and that multi-layered ICT skills, from lesson preparation to classroom instruction, student guidance, and ethics education, promote the spread ofIBL.

Therefore, it is important to clarify whether teachers' subject-specific expertise influences the implementation of IBL and whether teachers' attitudes and perceptions toward IBL influence its implementation. In addition, it is necessary to develop teacher training programs and instructional models that consider the important role that ICT skills play in improving IBL.

1.2. Problem Identification

In this paper, we discussed the importance of IBL, attitudes toward IBL, and the relationship between IBL and ICT skills and presented guidelines for enhancing IBL. However, the following issues remain.

First, the implementation of IBL in mathematics education has been identified as having unique challenges compared to other subjects. For example, Borromeo Ferri and Blum [14] reported that teachers attempting to introduce modeling activities in elementary school mathematics classes found it difficult to ensure the freedom of inquiry activities due to "familiarity with procedural problem-solving methods" and "abstract concepts that are difficult to verify." Additionally, Calleja and Buhagiar [15] revealed that in a Year 10 mathematics class, students' long-established, traditionally structured learning expectations conflicted with the introduction of inquiry-based investigations, leading to sustained resistance—even over time and with teacher support.

Second, it has become clear that teachers' attitudes toward IBL and the frequency of its implementation depend on their individual instructional beliefs (exam-focused vs. student-centered) [8].

In other words, factors such as educational beliefs and ICT utilization skills act as barriers or facilitators to IBL implementation [8],[13], and there are variable factors that cannot be fully explained by subject-specific practices. Of course, the influence of differences in specialized fields must also be considered. Third, despite the global advancement of ICT environments, there are significant disparities in ICT utilization skills among teachers, and differences in ICT skills lead to differences in IBL practices [13].

As described above, while the introduction of IBL is progressing in terms of institutional frameworks, there are complex factors such as individual differences and subject differences in teachers' acceptance attitudes and practical skills, as well as disparities in ICT skills, and it is urgent to establish systematic and evidence-based support measures to address these issues. However, the differences in attitudes toward IBL between mathematics teachers and other teachers are not clear. Furthermore, the relationship between ICT skills and attitudes toward IBL varies across subjects, and quantitative research comparing mathematics with other subjects such as science and social studies is limited. The influence of subject characteristics on attitudes and implementation of IBL remains unclear. Given the limited quantitative evidence comparing subject groups, this study takes an exploratory approach to examining potential differences and predictors of IBL-related attitudes among mathematics and non-mathematics teachers.

Taking these into account, this study aims to take the first step toward an integrated solution. We compare the attitudes toward IBL (perceptions, teaching confidence, and importance recognition) and inquiry process evaluation (freedom, teaching confidence, and evaluation) between mathematics teachers and other subject teachers in Japanese elementary, junior high, and high schools.

2. Method

2.1. Survey Participants and Survey Procedure

This study was conducted in summer 2022 through Intage, a survey company, targeting teachers working at public and private elementary, junior high, and high schools nationwide in Japan. As a result, 611 valid responses were obtained (119 mathematics teachers and 492 teachers of other subjects). After removing data where respondents showed inconsistencies in their answers—such as reporting “0 years of inquiry-based teaching experience” while also indicating they had such experience—the valid response rate reached 97.3%. Therefore, the reported response rate was calculated after data cleansing by the authors, based on the dataset provided by the survey company. Specifically, the response rate represents the proportion of valid responses among the panel members supplied by the company, not the proportion relative to the entire population of teachers in Japan.

Recruitment was conducted to avoid bias in the type of school where respondents worked, and a sample combining elementary, junior high, and high schools was ultimately obtained. Respondents were paid a specified number of points by the survey company.

2.2. Survey Items

The items shown in **Table 2.1** were used as survey items. ICT skills were treated as parametric data. Note that this study had a large sample size, and it was determined that parametric analysis could be used without any problems.

Table 2.1 Survey Items

Category	Variable / Item	Response Format
(1) Background (Facet) Items	Age	Open-ended (years)
	School Type	1 = Primary, 2 = Lower-secondary, 3 = Upper-secondary
	Inquiry-Based Learning (IBL) teaching experience	1 = None, 2 = < 1 yr, 3 ≈ 1–2 yrs, 4 ≈ 3–5 yrs, 5 ≈ 6–9 yrs, 6 = 10 yrs +
	Total teaching experience	Open-ended (years)
	Current subject(s) taught / disciplinary specialty	Open-ended (text)
(2) Attitudes toward IBL	Perceptions of IBL	5-point Likert: 5 = Very much, 4 = Somewhat, 3 = Neither, 2 = Not much, 1 = Not at all
	Confidence in teaching IBL	
	Perceived importance of IBL	7-point semantic differential:

		7: IBL ≻ 1: Traditional learning
(3) ICT-Use Skill (Checklist for Teachers' Ability to Teach ICT Use; MEXT, 2018[12]; Fukui et al., 2023[13])	ICTF1 "Ability to use ICT for researching teaching materials"	4 items for each factor, 4-point Likert 4 =I can do, 3 =Somewhat can do 2 = Can't do very well 1 = Can't do at all
	ICTF2 "Ability to use ICT in the classroom"	
	ICTF3 "Ability to guide students in the use of ICT"	
	ICTF4 "Ability to teach knowledge and attitudes"	

ICT skills consist of four factors. Factor 1 indicates the ability to utilize ICT in lesson planning, lesson preparation, and school administration, with a particular focus on the planned use of ICT prior to lessons. Factor 2 refers to the ability to utilize ICT during lessons, with a particular focus on the real-time use of ICT in actual lessons. Factor 3 is the ability to guide students in the use of ICT, including supporting the improvement of students' ICT skills. Finally, Factor 4 refers to the ability to guide students in acquiring the knowledge and attitudes that form the foundation for information utilization. This includes instruction in the attitudes and knowledge required in an information society. This sample is identical to that used in our previous study [13], which found that the internal consistency of ICTF1–ICTF4 was acceptable (Cronbach's $\alpha > .80$ for all items). Confirmatory factor analysis further indicated appropriate fit (e.g., GFI > .90, RMSEA < .10, SRMR < .05). Therefore, their use in this study was confirmed to be appropriate.

2.3. Analysis Procedure

As this study was not designed to test specific hypotheses, the analyses were conducted in an exploratory manner to identify potential patterns and relationships.

First, we conducted an intergroup comparison on the two groups "mathematics vs. other subjects" to examine consciousness toward IBL and verified the significance of differences between the groups. Next, we constructed a multiple regression model with the three perception items toward IBL as dependent variables, subject groups (dummy variable Grp, with mathematics as 0 and other subjects as 1), ICTF1–4, years of experience in inquiry-based instruction, and years of teaching experience as independent variables, and compared the effects of each. Through the above procedures, we comprehensively examined the influence of ICT skills and years of experience on attitudes toward IBL. Although the paper mentions a causal relationship, it is important to note that this is merely one aspect of the results and is only a correlation.

2.4. Ethical Considerations

The survey was conducted anonymously, and no personal information such as email addresses was collected. Participants were informed in advance that the survey results would not be used for any purpose other than research and that they could withdraw from the survey at any time. After completing the survey, the survey company awarded points to participants as specified. This survey was anonymous, and since it is not possible to identify individuals, responses cannot be withdrawn after submission.

3. Results and Discussion

We examined each item of the preliminary survey regarding attitudes toward IBL. These items were each calculated as single-item measures. The variables used in this study—perceptions, confidence in teaching, and perceived importance—are all ordinal-type Likert scales. However, upon examining the data distribution, the standard deviation for each variable exceeded 0.90, indicating that responses were dispersed across multiple categories rather than skewed toward a single category. That is, the dependent variables possessed sufficient spread and could be treated as variables retaining information content. Previous studies have also shown that when response distributions are moderately dispersed, 5-point or higher Likert scales can be approximated as interval scales, making the application of parametric methods valid [16], [17], [18].Based on these characteristics, this study adopted parametric analysis, considered robust under such conditions, rather than an ordinal logistic model. Therefore, in this study's analysis, each variable representing attitudes toward IBL was treated as a continuous variable.

We conducted Welch's t-test on three items related to attitudes toward IBL and four factors related to ICT skills in two groups (variable Grp) of "mathematics vs. other subjects" to verify the significance of differences between groups. The results are shown in **Table 3.1**.

Table 3.1 Comparison of IBL Attitudes and ICT Skills Between Subject Groups

Outcome	***Mean (Math Grp) (n = 119)***	***Mean (Other Grp) (n = 492)***	***t(df)***
Perceptions	3.24	3.34	t(178) = –1.02
Confidence	2.76	2.89	t(184) = –1.37
Importance	3.76	3.95	t(173) = –1.39
ICTF1	2.90	2.91	t(168) = –0.09
ICTF2	2.78	2.79	t(172) = –0.15
ICTF3	2.86	2.86	t(178) = –0.01
ICTF4	2.88	2.86	t(182) = +0.27

Based on the results in **Table 3.1**, no significant differences were detected in any of the items, and no main effects of subject groups were observed. In other words, no group differences were found between mathematics teachers and teachers of other subjects in terms of their perceptions of IBL, confidence in IBL, recognition of the importance of IBL, or each ICT skill.

Next, a multiple regression model was constructed with three items related to attitudes toward IBL as the dependent variables, subject groups, ICTF1–4, years of experience in inquiry-based instruction, and years of teaching experience as independent variables, to compare and examine their respective effects. The results are shown in **Table 3.2**.

Table 3.2 Multiple Regression Analysis Predicting IBL Attitudes

Outcome	***Predictor***	***Estimate***	***SE***	***t***
Perceptions	(Intercept)	+ 2.01	0.22	9.26***
	Grp	+ 0.09	0.09	0.99
	IBL Years	+ 0.12	0.02	5.90***
	Working Years	– 0.01	0.00	–1.80
	ICTF1	– 0.15	0.14	–1.02
	ICTF2	+ 0.07	0.14	0.49
	ICTF3	+ 0.32	0.15	2.11*
	ICTF4	+ 0.12	0.13	0.94

Confidence	(Intercept)	+ 1.25	0.21	5.84***
	Grp	+ 0.12	0.09	1.43
	IBL Years	+ 0.12	0.02	6.09***
	Working Years	– 0.00	0.00	–0.13
	ICTF1	– 0.41	0.14	–2.97***
	ICTF2	+ 0.43	0.14	3.06***
	ICTF3	+ 0.32	0.15	2.14*
	ICTF4	+ 0.09	0.13	0.75
Importance	(Intercept)	+ 3.11	0.31	10.10***
	Grp	+ 0.15	0.12	1.26
	IBL Years	+ 0.08	0.03	2.86***
	Working Years	– 0.02	0.01	–3.93***
	ICTF1	– 0.41	0.20	–2.03*
	ICTF2	+ 0.44	0.20	2.17*
	ICTF3	+ 0.16	0.22	0.74
	ICTF4	+ 0.18	0.18	0.71

***$p < .001$, *$p < .05$ ($n = 611$)

Note that the variable Grp is a dummy variable representing “teachers of other subjects,” with 0 indicating mathematics teachers and 1 indicating teachers specializing in other subjects. This allows us to evaluate the effect of “being a teacher of other subjects” on the dependent variable by comparing it with mathematics teachers (reference group) using this regression model. The results obtained from **Table 3.2** are shown below.

(1) Negative effects of ICTF1

The regression coefficient of ICTF1 was negative for all of Perception, Confidence, and Importance, and was statistically significant for Confidence and Importance in particular. Teachers with high ICTF1 scores tended to have lower attitudes toward these factors or to give conservative self-assessments of their attitudes toward IBL. This suggests that teachers who use ICT extensively in the pre-lesson material and lesson design stages may feel more confident in their prepared content and plans, and conversely, may feel more uncertain about unpredictable student-centered inquiry. As suggested by Koehler and Mishra [19]’s TPACK model and Voogt and Pareja Roblin [12], the integration of ICT and content knowledge contributes to the efficiency of lessons. However, the tendency to plan and control lessons may conflict with the essence of IBL, which is open questions that allow students to experiment and explore on their own, thereby suppressing positive attitudes toward IBL.

(2) Positive effects of ICTF2 and ICTF3

ICTF2 showed positive and significant correlations with Confidence and Importance, while ICTF3 showed positive and significant correlations with Perception and Confidence. In other words, teachers with higher ICTF2 and ICTF3 scores tended to have a higher attitudes toward IBL. The reason for this is that, unlike the “ICT as classroom management” pointed out by Ertmer and Ottenbreit-Leftwich [20], ICTF2 and ICTF3 in this study refer to a set of skills that embody “two-way interaction between teachers and learners” through ICT, such as providing real-time support to students during class, guiding them toward learning, and effectively utilizing ICT for instruction.

Teachers with these abilities can accurately support students' trial and error on the spot and smoothly provide feedback and hints when inquiry activities reach an impasse, which is likely to raise various levels of attitudes toward IBL.

(3) Impact of ICTF4

The regression coefficient for ICTF4 showed a positive trend but was not significant. Ribble [21] states that information ethics education (Digital Citizenship Education) is effective in improving students' attitudes toward Internet use, but it is not directly linked to innovation in teachers' teaching methods, particularly the adoption of new learning designs such as inquiry-based and project-based learning. Erstad [22] pointed out that ICT-based ethics and attitude guidance is effective in "sharing values" and "risk avoidance education," but its ability to enhance teachers' skills in designing learning experiences and remove psychological barriers to IBL is limited. In other words, lessons aimed at cultivating skills in information ethics and information morality education, or attitudes toward ICT, may differ somewhat in nature from the elements that foster teachers' self-efficacy, such as learning design and real-time support, which are at the core of IBL. Therefore, while such lessons may contribute to fostering a basic attitudes toward IBL, they may not lead to as direct improvements in self-assessment as other classroom support skills.

(4) ICTF1–ICTF3: A trade-off between preparation and in-class facilitation

The negative association of ICTF1 (ability to utilize ICT for preparing teaching materials and lesson planning) with teachers' attitudes toward IBL can be interpreted as a potential trade-off between preparation and flexibility. Teachers who invest heavily in ICT at the preparatory stage may develop highly structured lesson plans, which provide a sense of control and efficiency but may inadvertently reduce opportunities for student-generated questions or spontaneous inquiry paths. This tendency toward pre-structuring, while beneficial for content coverage, may conflict with the open-ended nature of IBL. As suggested by the TPACK framework [19], integrating ICT with content knowledge strengthens lesson design, but without complementary in-class facilitation skills (ICTF2–3), it may lead to conservative attitudes toward IBL. This finding highlights the need for professional development that balances preparatory ICT use with adaptive, student-centered classroom practices.

3.1. Implications for Mathematics Education

(1) Review of the preparatory stage (ICTF1)

The tendency for IBL attitudes to be modest when ICT is used effectively in teaching material research and lesson planning suggests that mathematics teachers tend to feel that they are good at preparation but lack confidence in actual practice. Training should include not only teaching material creation tools but also exercises that use ICT in actual classroom situations to support students' independent inquiry, with the aim of building consistent confidence in the transition from preparation to practice. It is also necessary to acquire the skills to facilitate independent inquiry in the classroom.

(2) Strengthening real-time support skills (ICTF2 and ICTF3)

Based on the results showing that ICT operation during class and ICT instruction to students enhance inquiry attitudes, honing these skills is likely to directly improve teachers' self-efficacy. In mathematics education, it is considered effective to focus on more practical workshops using dynamic geometry software such as GeoGebra and programming tools for visualization and numerical experiments. In other words, the ability to freely use ICT tools during class and guide students' operations leads to a sense of "I can support students well" in the field of IBL, which in turn promotes a positive attitude toward inquiry-based teaching methods.

(3) Importance of balance

Given that ICTF2 and ICTF3 have opposite effects to ICTF1, training programs need to be structured to develop "preparation skills" and "classroom support skills" in a balanced manner. Mathematics teachers are expected to acquire integrated ICT utilization skills across various processes of IBL (setting tasks, solving problems, and having students give presentations) through simulated lessons that combine advance preparation and real-time support.

(4) Non-significant results for ICTF4 (Information Ethics and Attitude Guidance Ability)

In educational settings, rather than conducting training on ICT attitudes and information ethics in isolation, it is considered essential to develop more integrated training programs that incorporate exercises in "ethical decision-making in inquiry design" in conjunction with ICTF2–3. This approach is expected to foster attitudes and attitudes toward ICT and enable teachers to actively utilize ICT in their lessons.

(5) Examples of inquiry-based mathematics activities utilizing ICT

The following examples show how mathematics teachers utilize ICT tools to implement IBL. This study emphasizes the negative correlation between ICTF1 (preparation before class) and attitudes toward IBL, as well as the importance of ICTF2 (use of ICT during class) and ICTF3 (guidance on ICT use by students). Furthermore, ICTF4 (ethics and attitudes toward ICT) may function independently of other skills and be most effectively developed in combination with real-time instructional practices. These examples reflect a shift in teachers' instructional attitudes from a control-oriented approach that requires careful preparation in advance to a facilitator role that supports students' free exploration activities.

Example 1: Sum of angles in triangles using GeoGebra (middle school geometry)

Students use GeoGebra to construct and manipulate triangles. Rather than being directly taught the rule for the sum of angles, students measure angles in various types of triangles and verify the rule themselves by dynamically dragging vertices. Teachers demonstrate and support the activity in real time (ICTF2) and prompt students to ask questions and confirm their observations (ICTF3). Teachers who adopt a flexible, inquiry-supportive approach can promote student autonomy and responsive instruction, which are important indicators of the effectiveness of IBL. ICTF4 can be implicitly introduced through discussions about accuracy, respect for digital tools, and responsibility in mathematical reasoning.

Example 2: Exploring quadratic functions using Desmos (high school algebra)

Students explore function transformations using Desmos sliders. They investigate how parameters affect the shape and position of graphs and derive generalizations. Rather than presenting properties as static facts, teachers use live demonstrations (ICTF2) to encourage students to interpret, predict, and justify their discoveries (ICTF3). The teacher's role shifts from content delivery to facilitating inquiry. ICTF4 applies when students discuss appropriate notation, collaborative sharing, and the importance of digital ethics when using shared graphing tools.

Example 3: Probability simulation using spreadsheets (upper elementary or lower middle school)

Students use spreadsheet functions (e.g.,=RANDBETWEEN,(1,6)) to simulate dice rolls, create histograms, and compare experimental and theoretical probabilities. Teachers guide students in interpreting patterns and anomalies (ICTF2), assist with troubleshooting formula errors, and encourage reflection on results (ICTF3). Rather than preparing fixed lesson outcomes (ICTF1), teachers promote the process of inquiry. ICTF4 is important when discussing the ethics of simulation, bias in randomization, and transparency in data interpretation.

(6) Additional examples of ICT-enhanced inquiry in mathematics

In addition to the previously presented cases, other areas of mathematics can also be effectively integrated with ICT to promote IBL:

a. Statistics and Data Science: Students collect authentic datasets (e.g., daily temperatures, sports results, or survey responses) and use spreadsheet software, R, or Python notebooks to visualize distributions, fit models, and test hypotheses. This promotes inquiry by encouraging students to generate research questions, explore variability, and critically interpret results. ICTF2 (in-class data manipulation) and ICTF3 (guidance on coding and visualization) play central roles in scaffolding these tasks.

b. Calculus: Dynamic graphing software such as GeoGebra or Desmos enables students to explore concepts of derivatives and integrals by manipulating functions and observing instantaneous rates of change or areas under curves. Rather than presenting formal definitions first, teachers use ICTF2 to demonstrate interactive examples and ICTF3 to guide students' exploratory reasoning, which helps them build conjectures about general principles.

c. Sequences and Recurrence Relations: Students can employ spreadsheet tools to generate recursive sequences, visualize patterns, and test generalizations (e.g., exploring the logistic map or Fibonacci sequence growth). Teachers facilitate student-led exploration by troubleshooting spreadsheet formulas (ICTF2) and guiding interpretation of emergent behaviors (ICTF3).

These additional cases reinforce the mapping between ICTF1–ICTF4 and mathematics education practices across diverse content areas. They highlight that ICT not only supports visualization and experimentation but also encourages students to engage in authentic cycles of questioning, testing, and refining ideas, which are central to IBL.

As a teacher reflection, these examples emphasize the need for teachers to recognize that real-time, responsive ICT use (ICTF2, ICTF3) promotes inquiry more effectively than static, pre-planned instruction (ICTF1). In IBL, there is a need to shift the mindset from a focus on meticulous preparation to one that promotes adaptive, learner-centered support that can be provided appropriately on the spot. Although ICTF4 is conceptually different, it can be developed by integrating it meaningfully into these dynamic learning environments. Furthermore, it is anticipated that without ICT, there would be a greater need for prior preparation in implementing IBL, and it may be difficult to instruct many students, highlighting the importance of ICT activities in IBL.

In summary, ICTF1 corresponds to pre-structuring activities, ICTF2 and ICTF3 to real-time support and guidance, and ICTF4 to reflective discussions on ethics and responsibility. This mapping shows how different ICT skills interact to scaffold inquiry processes in mathematics classrooms.

4. Conclusion

4.1. Summary of Our Research

This study examined whether there were differences in attitudes toward IBL between mathematics teachers and teachers of other subjects. The results showed that there were no significant differences in any of the indicators based on subject groups, and no major differences were found in the attitudes and evaluations of mathematics teachers and teachers of other subjects. Next, in a multiple regression analysis, we examined the effects of subject groups, ICT utilization ability factors, years of experience in inquiry-based instruction, and years of teaching experience as explanatory variables. The results showed that "ICTF2: ICT utilization ability during lessons" and years of experience in inquiry-based instruction had a positive influence on attitudes toward IBL. On the other hand, ICT utilization ability in teaching material research and preparation showed a negative effect, suggesting that teachers who use ICT to prepare lessons thoroughly tend to be cautious about IBL. These findings suggest that classroom-based ICT skills and prior experience in IBL are more influential on the acceptance and evaluation of IBL than subject characteristics such as mathematics and other subjects.

Previous studies have not compared mathematics teachers and teachers of other subjects while focusing on ICT skills and attitudes toward IBL, making this study novel and unique.

4.2 Limitations and Reflections for Future Research

This study provided important insights for enhancing IBL in the future, but many issues remain to be addressed.

First, there are limitations to the survey method. This study uses self-reported data based on a single-point survey, so it is not possible to determine the causal relationship between attitudes and ability. In the future, it will be necessary to conduct a longitudinal study that observes classroom practices and verifies the relationship with student learning outcomes, and to verify the results from multiple perspectives. In addition, since the sample was based on voluntary participation, it is possible that the percentage of teachers with a high level of interest in ICT was high. For generalization, stratified sampling or random sampling by region or school type is desirable.

Second, it is necessary to conduct comparisons between schools and between mathematics and other subjects. In this study, we analyzed data without distinguishing between elementary, middle, and high schools to identify overall trends. We also compared mathematics with other subjects. However, since curricula vary significantly depending on the stage of learning, there may be significant differences in attitudes toward IBL between science and liberal arts subjects. In the future, it will be necessary to expand the sample size and conduct a more detailed survey.

Third, it is necessary to clarify the background of the negative effects of ICTF1. Differences in the division of roles and time allocation between teachers who focus on creating teaching materials and those who provide practical inquiry support may have had an impact. To further investigate this issue, it will be necessary to conduct qualitative interviews and other research.

Based on the above considerations, it is necessary to compare and evaluate the effectiveness of practical ICT training programs and IBL promotion measures in Japan's subject curricula and accumulate further insights. These will be addressed as future challenges.

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