Japanese School Teachers' Attitudes and Awareness Toward Inquiry-based Learning Activities and Their Relationship with ICT Skills

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Abstract. This study examined Japanese teachers' attitudes and awareness toward inquiry-based learning (IBL) and its relationship to information and communications technology (ICT) skills, and aimed to gain basic knowledge for enhancing IBL. As technology advances at an accelerating pace, it is essential to develop human resources with skills to contribute to the development of science and technology. Enhancing IBL and science, technology, engineering, (arts), and mathematics (STEM/STEAM) education is important to achieve this goal. IBL is considered necessary in Japan and many other countries. It is expected to foster an attitude of addressing unfamiliar problems and to be an essential subject for students living in uncertain times. However, it is necessary to examine the kind of awareness that schoolteachers should have toward IBL to enhance it. This study focused on teachers' ICT skills and investigated their relationship with IBL. The results indicate that teachers with high ICT skills had a heightened awareness and a deeper understanding of IBL, and thus garnered a higher rate of IBL. Therefore, it is desirable to develop training programs based on these realities.

Keywords: ICT, Inquiry-based learning, STEM/STEAM, Teacher, Training program

1 Introduction

1.1 Purpose of this Study

This study aimed to explore the relationship between teachers' awareness and implementation of inquiry-based learning (IBL) and information and communications technology (ICT) skills, and to obtain basic knowledge for the future enhancement of IBL.

1.2 Research Background

In an information society that is advancing at an accelerating pace, there is a strong need to develop human resources to support the society. Technological innovations in artificial

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intelligence (AI) have been remarkable, and the future of society is often unpredictable. The arrival of "Singularity" [1] has been predicted for some time, and ChatGPT [2] has recently become an essential topic of conversation. Therefore, the importance of fostering human resources for science and technology is expected to increase.

School education is also required to develop the human resources for new science and technology. One of the most critical issues is cultivating an attitude toward addressing unfamiliar problems.

There are several such learning methods. For example, according to UNESCO [3], IBL is a process that provides learners with opportunities to construct their understanding of the complexity of the natural and human world around them. Hrast and Savec [4] stated that IBL is an instructional approach that can improve student learning outcomes and foster inquiry. Pedaste et al. [5] defined it as the process by which a learner develops a hypothesis, tests it through experimentation and observation, and discovers new causal relationships. Although there are several definitions of IBL, it is believed to play an important role in school education for fostering scientific thinking and an attitude toward addressing unfamiliar problems.

Science, technology, engineering, and mathematics (STEM) subjects, which incorporate technology and engineering education, in addition to traditional science and mathematics education [6], are gaining importance. In addition, broader science, technology, engineering, arts, and mathematics (STEAM) education has been advocated and widely practiced to address complex and diverse societal problems [7]. STEM/STEAM education often deals with cross-curricular content and actively uses ICT.

STEM/STEAM education incorporates inquiry-based activities, and the enrichment of IBL, which is a fundamental aspect of STEM/STEAM education and an important issue.

Hrast and Savec [4] stated that in IBL, the use of ICT plays an important role in the search, acquisition, analysis, and presentation of data and that the active use of ICT is important for the enrichment of IBL.

There are many examples of IBL using ICT, and it will become increasingly important to enhance IBL using various electronic devices and applications. Thus training teachers in these skills is also important.

1.3 Identification of Problems

When introducing ICT, it is crucial to consider teachers' and students' attitudes toward the use of ICT and IBL. Understanding teachers' attitudes makes it possible to develop more appropriate materials and design appropriate teacher-training programs.

Ghavifekr and Rosdy [8] surveyed teachers to ascertain the effectiveness of ICT in supporting teaching and learning processes in schools. The results showed that teachers' mastery of ICT tools is one of the main factors for successful technology-enhanced teaching and learning, and that teacher professional development training programs play an essential role in enhancing the quality of student learning.

Abdurrahman et al. [9] surveyed teachers' perceptions of STEM education and careers as a preliminary step toward designing inquiry-based STEM learning strategies. The results revealed that all the teachers recognized the importance of STEM in their education and careers. As mentioned above, there have been reports on teachers' awareness of ICT and STEM education.

Furthermore, surveys have been conducted on students regarding the relationship between their awareness of IBL and ICT skills; Hrast et al. [4] surveyed students' perceptions of ICT-enhanced IBL and found that most students reported that it had "a great deal" of positive effects on their mental processes. Regarding students' perceptions of the intended learning process, they reported that they were most impressed by the encouragement to think about the purpose of the experimental research, solve problems, and take responsibility for their learning. However, the relationship between teachers' perceptions of IBL and ICT skills has yet to be thoroughly examined. Such surveys should be conducted in the future to enhance IBL.

As technology develops rapidly and many applications are released one after another, adopting new technologies and knowledge, and actively using them in class are considered essential factors in enhancing the development of ICT-based classes. Therefore, teachers who have an attitude of trying to use electronic devices and applications for the first time may differ in their approach from those who do not believe in the use of such devices and application in terms of their awareness of how IBL addresses unfamiliar problems. In other words, teachers with high and low ICT skills may have differing attitudes toward IBL. However, these issues need to be thoroughly investigated. Therefore, the following research question was posed to address these problems in this study:

Research Question: Do different levels of ICT skills lead to different perceptions of IBL, importance of IBL, and confidence in IBL instruction?

In this study, an interaction between IBL and ICT skills is observed, and the relationship between ICT skills and the implementation and awareness of IBL is examined. Finally, suggestions for future training programs for IBL are suggested.

2 Methodology

2.1 Survey Targets and Procedures

In September 2022, an online survey was conducted by INTAGE HOLDINGS Inc., in Japan. Responses were obtained from 628 full-time teachers (418 male and 210 female). The mean age was 48.18 years (standard deviation (SD) 9.90), the mean length of service was 23.21 years (SD 10.86), and the response time was approximately 20 minutes. Data from 17 participants with inconsistent responses were excluded. Consequently, the number of valid responses was 611, and the valid response rate was 97.3%. No personally identifiable information, such as names or e-mail addresses, was collected.

2.2 Survey Items

Gender, age, school type, and years of service were selected as face items. To grasp the actual status of IBL, the following items were set as face items: implementation status of IBL ("I am currently teaching (hereafter, "currently teaching")," "I am not currently teaching but have taught before (hereafter, "currently teaching but have taught before")," or "I have never taught before (hereafter, "have never taught")"; number of years teaching IBL ("none," "less than 1 year," "1-2 years," "3-5 years," "6-9 years," or "over 10 years"); perception of IBL (5-point scale from "5: very good" to "1: not good at all"); importance of IBL (7-point Likert scale from "7: significant" to "1: not important at all"); and attitudes toward IBL, and confidence in teaching IBL (5-point Likert scale from "5: very much" to "1: not at all"). These measures were treated as nonparametric data.

Subsequently, to ascertain the ICT skills of the teachers, the checklist of teachers' ICT instructional skills provided by the Ministry of Education, Culture, Sports, Science and Technology [10] was used (4-point Likert scale from "4: I can" to "1: I can hardly"). This checklist comprised 4 factors and 16 items. The items on the list are shown in Table 1. Data on ICT instructional skills were treated as parametric.

Table 1. Checklist for Teachers' Ability to Teach ICT Use
(Ministry of Education, Culture, Sports, Science and Technology, 2018)

	Items
Factor 1: Ability to utilize ICT for researching teaching materials, preparing and evaluating instruction, and school duties (Ability to utilize ICT for researching teaching materials)	
1	Plan and utilize the computer and the Internet to improve education's effectiveness.
2	Utilize the Internet to collect teaching materials for classes and school work, and to disseminate information required for cooperation with parents and the local community.
3	Utilize word processing, spreadsheet, presentation software, and so on, to prepare handouts and materials necessary for classes, and documents and materials needed for classroom management and school administration.
4	Record and organize students' works, reports, worksheets, and so on, using computers to grasp their learning status and utilize them for evaluation.
Factor 2: Ability to use ICT in the classroom	
5	Present materials effectively using computers and presentation devices to increase students' interest, clarify issues, and have students summarize what they have learned.
6	Effectively present students' opinions by utilizing computers and presentation devices, to have students share and compare each other's opinions, ideas, work, and so on.
7	Consolidate knowledge and acquire skills, utilize learning software to have students work on repetitive tasks and tasks according to the level of understanding and proficiency of each student.
8	Effectively use computers and software for group discussions to summarize ideas and for collaborative work to produce reports, materials, and artwork.
Factor 3: Ability to guide students in the use of ICT	
9	Teach students to acquire the basic computer operation skills (typing, file operation, etc.) necessary for learning activities.
10	Teach students to use computers and the Internet to gather information and select reliable information according to their purposes.
11	Teach students to use word processing, spreadsheet, presentation software, and so on, to organize their research and thoughts and to summarize them in sentences, tables, graphs, and so on.
12	Teach students to use computers and software to exchange and share their thoughts and ideas.
Factor 4: Ability to teach the knowledge and attitudes that form the basis of information use (Ability to teach knowledge and attitudes)	
13	Teach students to take responsibility for their actions when participating in the information society, respect others and their rights, and follow the rules in gathering and disseminating information.
14	When using the Internet, teach students to avoid antisocial behavior, illegal activities, and Internet crimes, and use the Internet appropriately while caring for their health.

15	Teach children and students to set and manage passwords appropriately, based on basic information security knowledge, and safely use computers and the Internet.
16	Help students realize the convenience of computers and the Internet, motivate them to use them in their studies, and understand how they work.

2.3 Analysis Procedure

First, a simple tabulation was conducted for each survey item; the ICT-use instructional ability scores were calculated as the mean of the four lowest scores for each factor. Next, the upper and lower groups were established based on the mean score of each factor for each participant's ability to teach using ICT. Subsequently, the χ^2 test was used to analyze whether there were differences between the groups regarding the number of people who were implementing IBL and the number of years they had been teaching IBL. Finally, the image/perception of, importance of, and confidence in IBL were analyzed using Wilcoxon's rank-sum test (two-tailed). To understand teachers' awareness and actual conditions, the analysis was conducted without distinguishing by gender, school type, and so on. R version 4.2.3 was used for the analysis, and the significance level was set at 5%.

3 Results

3.1 Preliminary Analysis

The results of the confirmatory factor analysis (CFA), which provides information about the reliability and validity of the measurement model used, for the four constructs related to the implementation of inquiry-based learning are presented in Table 2. While we understand that the threshold values for fit indicators are not absolute rules and that the assessment of the model fit should consider multiple fit indices together rather than relying on a single indicator, these indicators are used as the guidelines for assessment of model fit in this study: Goodness-of-Fit Index (GFI) value above 0.90, Root Mean Square Error of Approximation (RMSEA) value below 0.08, and Standardized Root Mean Square Residual (SRMR) value below 0.08 [11], [12], [13].

Overall, the results suggest that the measurement model used for assessing the implementation of inquiry-based learning has good internal consistency and fits the data reasonably well. The variables related to the abilities of using ICT and teaching knowledge and attitudes demonstrate reliable and valid measurements based on the given indicators as shown in Table 2.

Table 2. Descriptive Statistics of Implementation of Inquiry-based Learning.

Variable	α	GFI	RMSEA	SRMR
Ability to use ICT for researching teaching materials	0.874	0.994	0.064	0.012
Ability to use ICT in the classroom	0.892	0.998	0.023	0.007
Ability to guide students in the use of ICT	0.900	0.992	0.082	0.012
Ability to teach knowledge and attitudes	0.880	0.997	0.044	0.009

3.2 Descriptive Statistics

Table 3 shows that 183 (30.0%) of the respondents “currently teaching” IBL, 187 (30.6%) “currently do not teach but have taught,” and 241 (39.4%) “have never taught.” The χ^2 test was used to analyze whether there was a difference in the number of teachers who had implemented IBL, and a significant difference was found between the items. Furthermore, multiple comparisons (Ryan’s method) revealed that the number of teachers in the group that had never conducted IBL was significantly higher at the 5% level than the number of teachers in the other two groups.

Table 3. Descriptive Statistics of Implementation of Inquiry-based Learning.

Implementation of inquiry-based learning	*n*	χ^2	Multiple Comparison (Ryan Method)
Currently teaching	183		
Currently do not teach but have taught	187	10.30**	Have never taught > currently teaching, currently do not teach but have taught
Have never taught	241		

**$p < .01$ (n = 611)

Table 4 shows that 241 (39.4%) of the respondents had “none,” 27 (4.4%) had “less than 1 year,” 100 (16.4%) had “1-2 years,” 109 (17.8%) had “3-5 years,” 40 (6.5%) had “6-9 years,” and 94 (15.4%) had “more than 10 years” of IBL instruction. The number of respondents teaching for “more than 10 years” was 94 (15.4%). A χ^2 test was used to analyze whether there was a difference in the number of years of IBL instruction, and significant differences were found among the items. Furthermore, multiple comparisons (Ryan’s method) revealed that the number of teachers in the group with no IBL instruction was significantly higher than in the group with a few years of IBL instruction. The number of teachers in the groups with 1-2 years, 3-5 years, and over 10 years of IBL instruction was significantly greater than those with less than 1 year of IBL instruction and those with 6-9 years of IBL.

Table 4. Descriptive Statistics of Years of Teaching Inquiry-based Learning.

Years of teaching inquiry-based learning	*n*	χ^2	Multiple Comparison (Ryan Method)
None	241		
Less than 1 year	27		None > less than 1 year, 1 to 2 year(s),
1-2 years	100	283.86 **	3 to 5 years, 6 to 9 years, over 10 years
3-5 years	109		1 to 2 year(s), 3 to 5 years, over 10 years
6-9 years	40		> less than 1 year, 6 to 9 years
More than 10 years	94		

**$p < .01$ (n = 611)

Table 5 shows that the mean of the perception of IBL was 3.32 (SD 0.91), the mean of the importance of IBL was 3.91 (SD 1.24), and the mean of the confidence of teachers in using ICT for teaching IBL was 2.87 (SD 0.92). The analysis of these subjects followed.

Table 5. Descriptive Statistics of Consciousness of Inquiry-based Learning.

Consciousness of inquiry-based learning	M	SD

Perception of inquiry-based learning	3.32	0.91
Importance of inquiry-based learning	3.91	1.24
Confidence in instruction	2.87	0.92

(n = 611)

3.3 Relationship between the Consciousness of Inquiry-based Learning and ICT Skills

Here, the upper and lower groups were set based on the mean score of each factor of each subject's ability to teach using ICT. The χ^2 test was used to analyze whether there were differences in the number of teachers in the implementation of IBL and the number of years of teaching IBL between the groups. The results are shown in Tables 6 and 7.

Table 6 shows a significant difference in the number of teachers in the upper and lower groups for all ICT instructional ability factors. Residual analysis showed that the number of teachers in the upper group who conducted inquiry activities and those in the lower group who had never undertaken inquiry activities was significantly higher. In comparison, the number of teachers in the upper group who had never conducted inquiry activities and those in the lower group who were currently working on inquiry activities, were significantly lower.

Table 6. Relationship between ICT Skills and Implementation of Inquiry-based Learning.

		Implementation of Inquiry-based Learning			χ^2
		Currently teaching	**Currently do not teach but have taught**	**Have never taught**	
Ability to use ICT for researching teaching materials	upper	135▲	125	121▽	26.92 **
	lower	48▽	62	120▲	
Ability to use ICT in the classroom	upper	125▲	104	107▽	24.06 **
	lower	58▽	83	134▲	
Ability to guide students in the use of ICT	upper	132▲	118	121▽	21.60 **
	lower	51▽	69	120▲	
Ability to teach knowledge and attitudes	upper	130▲	121	117▽	24.22 **
	lower	53▽	66	124▲	

**$p < .01$ (df = 2, n = 611)

▲: Significantly more items as a result of residual analysis ($p < .05$)

▽: Significantly less items as a result of residual analysis ($p < .05$)

Table 7 shows significant differences in the number of years of teaching IBL between the upper and lower groups for all factors of using ICT to research teaching materials and teaching knowledge and attitudes. Residual analysis showed that there was a significant difference in the number of years of inquiry-based instruction between the upper and lower groups for the ability to use ICT for researching teaching materials and the ability to teach knowledge and attitudes; the upper group had 3-5 years, 6-9 years, and over 10 years of inquiry-based instruction, and the lower group had never conducted inquiry-based instruction. Regarding the ability to use ICT in the classroom, the number of teachers in the upper group who had conducted inquiry-based instruction for 3-5 years, 6-9 years, and over 10 years, and those in the lower group who had taught inquiry for 3-5 years, 6-9 years, and over 10 years, were significantly more extensive than those in the ICT skills lower group. The upper group that had never had inquiry instruction for 3-5 years, 6-9 years, and over 10 years, and the lower group that had never had inquiry instruction and had had inquiry instruction for less than 1 year were significantly more in number, while the upper group that had never had inquiry instruction and had had inquiry instruction for less than 1 year, and the lower group that had had inquiry instruction for 3-5 years, 6-9 years, and over 10 years were significantly fewer. Regarding the ability to guide teachers in the use of ICT, the upper group that had been providing inquiry instruction for over 10 years and the lower group that had never provided inquiry instruction had significantly larger numbers of teachers, whereas the upper group that had never offered inquiry instruction and the lower group that had provided inquiry instruction for over 10 years had significantly fewer numbers of teachers. The number of teachers in the upper group who had been conducting inquiry instruction for over ten years and the lower group who had never conducted inquiry instruction was significantly smaller than that of the ICT skills lower group.

Table 7. Relationship between ICT Skills and Years of Teaching Inquiry-based Learning.

		Years of Teaching Inquiry-based Learning						
		None	**Less than a year**	**1-2 years**	**3-5 years**	**6-9 years**	**More than 10 years**	χ^2
Ability to use ICT for researching teaching materials	upper	121▽	13	65	77▲	31▲	74▲	35.60 **
	lower	120▲	14	35	32▽	9▽	20▽	
Ability to use ICT in the classroom	upper	107▽	9▽	51	72▲	32▲	65▲	39.80 **
	lower	134▲	18▲	49	37▽	8▽	29▽	
Ability to guide students in the use of ICT	upper	121▽	12	59	75	30	74▲	33.47 **
	lower	120▲	15	41	34	10	20▽	
Ability to teach knowledge and attitudes	upper	117▽	14	59	73▲	30▲	75▲	35.31 **
	lower	124▲	13	41	36▽	10▽	19▽	

**$p < .01$ ($df = 5$, $n = 611$)

▲: Significantly more items as a result of residual analysis (p < .05)

▽: Significantly less items as a result of residual analysis ($p < .05$)

Perceptions of IBL were analyzed using the Wilcoxon rank-sum test (two-sided). Table 8 shows the significant differences between the upper and lower groups in all factors of ICT instructional skills, with the upper group showing a higher perception of IBL than the lower group.

Table 8. Relationship between ICT Skills and Perception of Inquiry-based Learning.

		n	**Perception of Inquiry-based Learning**		***W***
			M	**SD**	
	upper	381	3.47	0.90	54743.5 **

Ability to use ICT for researching teaching materials	lower	230	3.07	0.88	
Ability to use ICT in the classroom	upper	336	3.52	0.87	58199.5 **
	lower	275	3.08	0.90	
Ability to guide students in the use of ICT	upper	371	3.51	0.88	57620.5 **
	lower	240	3.03	0.88	
Ability to teach knowledge and attitudes	upper	368	3.47	0.91	55179.5 **
	lower	243	3.09	0.87	

**$p < .01$ (n = 611)

The importance of IBL was analyzed using a two-sided Wilcoxon rank-sum test (two-sided). Table 9 shows the significant differences between the upper and lower groups in all factors of ICT instructional skills, with the upper group assigning higher importance values to IBL than the lower group.

Table 9. Relationship between ICT Skills and Importance of Inquiry-based Learning.

		n	**Importance of Inquiry-based learning**		***W***
			M	**SD**	
Ability to use ICT for researching teaching materials	upper	381	4.04	1.23	51231 **
	lower	230	3.69	1.22	
Ability to use ICT in the classroom	upper	336	4.14	1.21	56395 **
	lower	275	3.64	1.23	
Ability to guide students in the use of ICT	upper	371	4.08	1.21	53672.5 **
	lower	240	3.65	1.24	
Ability to teach knowledge and attitudes	upper	368	4.05	1.22	52344 **
	lower	243	3.70	1.24	

**$p < .01$ (n = 611)

Wilcoxon’s rank-sum test (two-sided) was used to analyze confidence in IBL-instruction. Table 10 shows a significant difference between the upper and lower groups in all factors of ICT instructional skills; the upper group had higher confidence in teaching IBL than the lower group.

Table 10. Relationship between ICT Skills and Confidence in Instruction of Inquiry-based Learning.

		n	**Confidence in Instruction**		***W***
			M	**SD**	
Ability to use ICT for researching teaching materials	upper	381	3.05	0.93	57169 **
	lower	230	2.56	0.81	
Ability to use ICT in the classroom	upper	336	3.13	0.90	62318.5 **
	lower	275	2.55	0.83	
Ability to guide students in the use of ICT	upper	371	3.09	0.92	59869.5 **
	lower	240	2.52	0.79	
Ability to teach knowledge and attitudes	upper	368	3.05	0.92	56828 **
	lower	243	2.59	0.84	

**$p < .01$ (n = 611)

The results indicate that teachers with high ICT utilization skills had significantly more experience in teaching IBL than teachers with low ICT utilization skills. General perceptions, perceptions of importance, and confidence in IBL were all high.

4 Discussion

The survey results revealed that not only the implementation but also the awareness of IBL differed depending on the ICT skills of the participants. The group with high ICT skills showed a difference in awareness of IBL compared with the group with low ICT skills.

The reason for this is that teachers who have not yet mastered ICT have low skills in using ICT and may not have considered the possibility of using ICT in their classes in depth. Therefore, it is assumed that acquiring the ability to use ICT will not only enhance classes in various subjects but also enable teachers to think about how to use ICT in IBL to address unfamiliar problems, and may lower the hurdles to IBL. Furthermore, it is assumed that improving ICT skills, such as designing classes and finding appropriate applications for IBL, plays an important role in fostering awareness of IBL. Therefore, it is assumed that improving ICT skills is an important factor in enhancing future IBL.

For example, when training on IBL is provided to a group with high ICT skills, it is considered effective to present various examples of IBL while practicing it, and to conduct activities that encourage teachers to conduct IBL using ICT.

However, the group with low ICT skills had low awareness of IBL. They rarely engaged in IBL, suggesting that improving their ICT skills is important. As the results have shown, ICT is important to enhance IBL. When conducting training on IBL, it may be effective for teachers with low ICT skills to first improve their ICT skills and then conduct training on IBL once their self-efficacy is enhanced. However, it may not be effective to provide training on ICT skills to teachers with low ICT skills after conducting training on IBL, because it is assumed that the hurdle will be higher for teachers with low ICT skills.

These results suggest that focusing on the status of ICT skills may be effective for developing IBL training programs.

4.1 Limitations and Reflections for Future Research

Although the results of this study suggest important findings, there are some limitations.

This study was limited to teachers in Japan, and it is unclear whether the results are applicable to other countries. In addition, it was not possible to examine differences in subject areas, ICT facilities in schools, years of teaching experience, and other factors that may have affected the results.

To resolve the above limitations, it is necessary to engage in continuous research and develop these findings into a study to compare data from different countries to find a better method of IBL.

5 Conclusion

This study aimed to explore the relationship between teachers' awareness and implementation of IBL and ICT skills, and to obtain basic findings for the future enhancement of IBL. The results of the study revealed that the group of teachers who considered themselves to have high ICT skills conducted more IBL, taught longer, and had significantly higher perceptions of IBL higher perceptions of the importance of IBL, and confidence in teaching IBL than the group of teachers who did not consider themselves to have high ICT skills. Based on these results, directions have been proposed for training in IBL. This is an unprecedented study and provides important findings for enhancing IBL. To address the limitations of this study regarding lack of applicability to other countries and lack of consideration of other influencing factors, continuous research should be conducted to compare data from different countries and find a better method of IBL. Enhancing IBL is expected to be important for developing human resources that will play active roles in science and engineering.

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