Elementary Science Teachers' Understanding of Inquiry-Based Teaching and Self-Evaluation of their Practices: A Case Study from Thailand

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Abstract

This research explores Thai elementary science teachers' understanding of inquiry-based teaching based on self-evaluation, and focusing on the frequency of their use of inquiry-based strategies in a class. We developed 18 open-ended questions on teaching scenarios based on the essential features of inquiry teaching to assess 38 Thai elementary science teachers' understanding of inquiry-based teaching. The 14 items of the Inquiry Strategies Scale (IS) were used to measure the frequency of using inquiry-based teaching strategies in a lesson delivered by each of the study participants. The results reveal that these Thai science teachers lack knowledge and have some fundamental misunderstandings about inquiry-based science teaching. Interestingly, the frequency with which they used inquiry-based strategies in science teaching was almost the same as non-inquiry-based strategies and was not related to their knowledge. Specific scaffolding is needed to help the teachers gain a better understanding of inquiry-based science teaching.

Introduction

Inquiry-based teaching plays an important role in teaching and learning science (American Association for the Advancement of Science [AAAS], 1990) and is promoted widely in the science education domain (Balogová & Ješková, 2018; Dobber, Zwart, Tanis, & van Oers, 2017; Wangdi, Precharattana, & Kanthang, 2020). In Thailand, inquiry-based teaching is promoted by the Institute for the Promotion of Teaching Science and Technology (IPST), which provides training programs for developing teachers' attitudes and teaching based on inquiry strategies. Most training programs aim to improve teachers' pedagogical content knowledge about inquiry-based teaching and assist teachers in teaching science based on inquiry strategies (Greca, 2016; Martins-Hansen, 2020). Previous studies indicate that teachers who lack knowledge and skills about inquiry-based teaching will reduce inquiry-based activities in a class (Crawford, 2000; Crawford, Zembal-Saul, Munford, & Friedrichsen, 2005) and have a limitation in engaging students to learn, especially science in a real-world situation (Darling-Hammond, 2006). Thus, identifying teachers' understanding of inquiry-based teaching is the first step towards guiding appropriate teachers' professional development programs, that emphasise improving teachers' knowledge and attitudes towards an inquiry-based teaching method (Ladachart, 2020). This is to ensure students achieve meaningful learning with high levels of inquiry (Capps, Crawford, & Constas, 2012; Creagh & Parlevliet, 2014; Zion, Schwartz, Rimerman-Shmueli, & Adler, 2020).

According to the growing science education research, many educators use inquiry-based teaching in different dimensions (Asay & Orgill, 2010; Braun, Kirkup, & Chadwick, 2018; Martin-Hansen, 2002). However, numerous studies report that teachers' misconceptions about inquiry-based teaching in different contexts are increasing (Harwood, Hansen, & Lotter, 2006; Kang, Orgill, & Crippen, 2008). In Thailand, we found that although Thai science teachers had experiences of inquiry-based instruction training, they could not differentiate between inquiry- and non-inquiry-based activities (Luecha & Kaewkhong, 2018).

It is necessary to explore science teachers' understanding of inquiry-based teaching concepts (Aydeniz, Bilican, & Senler, 2021; Kang et al., 2008) to design the proper scaffolding to support their inquiry-based class teaching (Zion et al., 2020). This study investigates Thai science teachers' understanding of inquiry-based science teaching, based on self-evaluation and how frequently they use inquiry-based strategies in a class. Both teachers' understanding and their self-evaluation about inquiry-based teaching are determined and the trend of correlations is discussed. The research questions this study addresses are:

1. What do Thai elementary science teachers understand about inquiry-based teaching in terms of levels of inquiry and the essential features of inquiry?
2. How often do Thai elementary science teachers use inquiry-based strategies in a class?
3. How does Thai elementary science teachers' understanding of inquiry-based teaching correlate with the frequency in which they use inquiry-based strategies?

Literature review

The essential features and levels of inquiry-based teaching

The National Research Council (NRC, 2000) defined five essential features of inquiry teaching: (1) engage in scientifically oriented questions; (2) give priority to evidence; (3) formulate explanations from evidence; (4) evaluate explanations in light of alternative explanations; and (5) communicate and justify explanations. The NRC promotes eight practices that are essential for learning K–12 science and engineering based on the essential features of inquiry-based teaching (NRC, 2012). Besides, the four levels of inquiry-based teaching determined from teachers' and students' roles in a class, teacher-directed, structured, guided, and open inquiry have been mentioned in the science education field. Both essential features and levels of inquiry-based teaching have an inseparable relationship (Banchi & Bell, 2008). The essential features and levels of inquiry teaching have been widely used as a framework to help teachers understand and enact inquiry-based instruction in science classrooms (Asay & Orgill, 2010; Crawford, 2000; Crawford et al., 2005).

Understanding of inquiry-based teaching

Prior studies (Rop, 2002; Van Driel, Beijaard, & Verloop, 2001) indicate that teachers' knowledge about inquiry-based teaching has positive correlations with their teaching of science in a class. However, many science teachers do not understand the nature of the inquiry (Abd-El-Khalick et al., 2004; Kang et al., 2008; Trumbull, Scarano, & Bonney, 2006). The essential features of inquiry were not as widely understood (Bodzin & Beerer, 2003), teaching practices were informed by individual teachers' conceptions of classroom inquiry (Wallace & Kang, 2004). Furthermore, Kang et al. (2008) found that although the teachers could identify teaching scenarios that were examples of classroom inquiry, their reasons rarely mentioned the features of 'evaluating explanations in connection with scientific knowledge' and 'communicating explanations', relating to Seung et al.'s (2014) report that the teachers did not encourage students to generate their explanations, they did not ask students to connect the data from the exploration phase to the scientific explanation.

Supporting science teachers to have a better understanding of inquiry-based teaching is necessary (Lee, Hart, Cuevas, & Enders, 2004; Schwartz, Lederman, & Abd-el-Khalick, 2012). Assessing their understanding of inquiry-based teaching is the first step towards helping them to develop skills for inquiry class management (Seung, Park, & Jung, 2014).To assess teachers' understanding of inquiry-based teaching, several sources of teaching evidence have been used, such as determining teachers' teaching behaviour, or how often various strategies were used in the class compared with teachers' self-evaluation test, for instance, the "Science Teacher Inquiry Rubric" (STIR; Bodzin & Beerer, 2003); interviews, discussions, written responses to teaching scenarios (Kang & Wallace, 2005); and teaching skills evaluation form, digital video recording, and learning gains evaluation forms (Corlu & Corlu, 2012). In this study, the 18 science teaching scenarios, developed based on the national science curriculum and essential features of inquiry instruction (NRC, 2000), were used to explore teachers' understanding of inquiry-based teaching.

Self-evaluation

A self-evaluation allows teachers to reflect on their teaching and learning goals, challenges, and accomplishments. It is a valuable tool for exploring how frequently teachers enact various aspects of investigative teaching in their classrooms (Lee et al., 2004; Schraw, Crippen, & Hartley, 2006), such as self-evaluation of inquiry in science teaching. Bodzin and Beerer (2003) developed the Science Teacher Inquiry Rubric (STIR) based on the national science education standards and essential features of inquiry instruction (NRC, 2000), to position the rubric as both an observation tool and a self-reflection instrument. While the STIR was not reliable enough to use as a self-assessment instrument, it had potential to be used as a tool for teachers to assist them in gauging their inquiry-based classroom instructional strategies. In Lee et al. (2004), self-report survey data, classroom observations, and focus group interviews were used to measure change in teachers' opinions on the importance of science content, discourse and inquiry-based knowledge, and their practices of inquiry and discourse through classroom observations, both before and at the end of a large-scale professional development program intervention. The results showed that the teachers appeared to rate their knowledge and beliefs in inquiry more highly than they were rated in practice. Another instrument, Teaching Science as Inquiry (TSI; Smolleck, 2004), was used to measure teachers' self-efficacy in inquiry-based instruction; however there were some overlapping items in the instrument and limitations.

Lakin and Wallace (2015) developed two validated self-report instruments for measuring the frequency of inquiry used in the classroom, including the Inquiry Strategies Scale (IS), which listed common instructional strategies with non- and inquiry strategies intermixed, and the 5Es Inquiry Scale. This study used only the Inquiry Strategies Scale (IS) to investigate self-reporting for the frequency that teachers used inquiry-based strategies in practice. There were 11 inquiry items on the IS scale, and another 3 items were included to measure non-inquiry strategies. The Likert-type scale had five anchor points: never, rarely (a few times a year), sometimes (once or twice a month), often (once or twice a week), all or almost all science lessons.

Methodology

This study was the first phase of a project developing professional developing workshops on inquiry-based teaching for Thai elementary science teachers in the north of Thailand. Teachers' understanding of inquiry-based teaching, experience with inquiry-based teaching, and the trainings of each teacher, were investigated using online questionnaires in Google Forms, during January 2021, in accordance with the guidelines of the Declaration of Helsinki. All procedures for this study were approved by the Chiang Mai University Research Ethics Committee (COE No. 002/64). All participants agreed to participate voluntarily in the research. This study employed a mixed-methods research approach (Creswell & Clark, 2017) using qualitative and quantitative data as a primary data source, teachers' understanding of inquiry-based teaching, and use of inquiry strategies, respectively. The data were analysed using both qualitative and quantitative analysis approaches.

Participants

Participants consisted of 38 (78.9% female and 21.1% male) elementary science teachers (grades 1st-6th, children between ages of 6 and 11 years) of a large private school in Chiang Mai, Thailand, aged from 30 to 40 years old. Their teaching experience ranged from 11 to 20 years. Twenty-two participants graduated with a bachelor's degree and the other 16 participants graduated with a master's degree in education. The teachers were selected by purposive sampling according to convenience, they were contacted via phone call to solicit their participation in the research program. They voluntarily responded to the call to complete the online questionnaires about their understanding of inquiry-based teaching and use of inquiry strategies during January 2021. Finally, they were interviewed and selected on the basis of who had received previous training in teaching science by inquiry strategies.

Instruments

This study used questionnaires to measure teachers' understanding of inquiry-based teaching and self-evaluation of their use of inquiry-based strategies in science classes. The first instrument developed by the researchers consists of 18 open-ended questions designed with consideration of the essential features and levels of inquiry-based teaching, as described in Table 1 (NRC, 2000; Zion & Mendelovici, 2012). Each item was a teaching scenario representing inquiry activities, either mentioning all, or lacking some, essential features of inquiry-based teaching, determined the index of item objective congruence (IOC) and content validity by 5 experts in science teaching. The questionnaires were trialed with 174 non-sample groups of science teacher students who were selected via purposive sampling to find discrimination, which is between 0.78 and 0.8. The reliability of the questionnaires was determined using Cronbach's alpha and found to be 0.82. The index of item objective congruence (IOC) is between 0.67 and 1.0, which is higher than 0.5. Both the 174 science teacher students and research participants had experience in teaching by inquiry strategies from their studies and training, respectively. However, before the questionnaires were trialed with the 174 science teacher students, they were instructed on the essential features of inquiry-based teaching. The participants were asked to identify which items were inquiry-based science teaching and to support their response with reasons. Their responses were categorized by a scoring method discussed later in this paper.

Secondly, the teachers' self-evaluations were assessed using questionnaires developed by Lakin and Wallace (2015), consisting of 14 items/factors, as shown in Table 2. Eleven inquiry items were from the IS scale, and another 3 items were included to measure non-inquiry strategies ('Listen to a lecture about science', 'Copy notes or problems off the board', and

‘Memorise formulas and facts for a test or quiz’). It was a 5-level estimation questionnaire (all activities=5, often=4, sometimes=3, rarely=2 and never=1). All questions were translated into the Thai language and the index of item objective congruence (IOC) and content validity was determined by 5 experts in science teaching. The IOC of these questions is between 0.67 and 1.0, higher than 0.5. All of these questions were also trialled with 174 non-sample groups of science teachers to find discrimination, which was between 0.90 and 0.91. The reliability of this questionnaire was determined using the Cronbach alpha coefficient, 0.91. These questions will reflect how often each teacher uses inquiry strategies in their practice.

Table 1. Items used for measuring teachers’ understanding of inquiry-based teaching classified by levels of inquiry and five essential features of inquiry-based teaching.

Levels of inquiry-based teaching	Items from questionnaires mentioning all five essential features of inquiry-based teaching	Items that lack some essential features of inquiry-based teaching
Open inquiry	10, 11	5 (none of the 3rd feature) 17 (none of the 5th feature)
Guided inquiry	7, 12	1 (none of the 4th feature) 3 (none of the 4th feature)
Structured inquiry	2, 4	8 (none of the 5th feature) 14 (none of the 1st feature) 15 (none of the 2nd feature)
Confirmation inquiry	9, 13	6 (none of the 1st feature) 16 (none of the 3rd feature) 18 (none of the 2nd feature)

Table 2. Factor solutions for Inquiry Strategies Scale (IS)

	Factor solutions for Inquiry Strategies Scale (IS)
Inquiry strategies	1) Participate in small groups to make sense of science 2) Give an explanation about how they solved a science problem or designed an experiment 3) Use technology (e.g., probes, cameras) to learn science 4) Explain concepts to me or to another student 5) Design and conduct their own experiment or scientific investigation 6) Do science projects or investigations that take several days to complete 7) Apply science situations to life outside of school 8) Discuss alternative explanations for a question or problem 9) Explore questions created by students 10) Analyse data using charts, tables, or graphs 11) Write about the results of scientific investigations
Non-inquiry strategies	12) Listen to a lecture about science 13) Copy notes or problems off the board 14) Memorise formulas and facts for a test or quiz

Data analysis

Assessing teachers' understanding of inquiry-based teaching

In assessing teachers' understanding of inquiry-based teaching, their responses to the questionnaires were categorised into groups, using the criteria applied from Uce (2015), with a consensus of three researchers using the following labels and scores: *understanding* (2 points) – the responses identifying whether teaching scenarios in the questionnaires are inquiry-based teaching or not are correct and using a correct reason based on the essential features of inquiry-based teaching; *partial understanding* (1 point) – the responses identifying whether teaching scenarios in the questionnaires are inquiry-based teaching or not are correct, but reasons supporting their responses are not related; *incorrect understanding* or *no answers* (0 point) – responses that fail to identify whether teaching scenarios in the questionnaires are inquiry-based teaching or not; no answers/responses. An example of response analysis is shown in Figure 1. The teaching scenario of item 3 mentions a teacher who has started teaching on the topic of plants characteristics by asking students "*Are there any characteristics of the trees of the garden in our school that are the same or different? Can you group the trees into groups, how?*" Then the teacher assigns students to survey the trees in the garden in groups, for 20 minutes with the necessary survey equipment. The teacher let students design their notetaking and draw a picture representing the characteristics of each tree that they explore. Then, the teacher asks students in each group to present their data and answers to the question that he/she had asked before starting the survey activity, in front of the class. As shown in Table 1, this teaching scenario is classified as "Guided inquiry level", but the 4th feature (evaluate explanations in light of alternative explanations) does not appear. Therefore, the A and B responses shown in Figure 2 are classified as *partial understanding* (1 point). And the C response is classified as *incorrect understanding* or *no answers* (0 point). The percentage of participants classified into each group of understanding is represented according to each item and the levels of inquiry-based teaching, respectively. The reasons used for supporting their answers were determined after debate among the researchers to identify teachers' understandings and misconceptions. Each teacher can have more than one understanding and misconception.

Thai version

ข้อ 3 ครูเริ่มกิจกรรมการเรียนรู้เรื่อง ลักษณะของพืช โดยการถามว่า"นักเรียนคิดว่า ต้นไม้ต่าง ๆ ในบริเวณสวนหย่อมของโรงเรียน มีลักณะใดที่เหมือนหรือแตกต่างกัน ถ้าต้องการจัดกลุ่มต้นไม้ในบริเวณส่วนหย่อมของโรงเรียน นักเรียนจะจัดกลุ่มอย่างไร" จากนั้นครูมอบหมายให้นักเรียนจับกลุ่มเพื่อสำรวจต้นไม้ในบริเวณสวนหย่อมของโรงเรียน เป็นเวลา 20 นาที โดยมีอุปกรณ์ที่จำเป็นในการสำรวจแจกให้แต่ละกลุ่ม ครูเปิดโอกาสให้นักเรียนออกแบบการจดบันทึกและวาดรูปลักษณะของต้นไม้ที่นักเรียนได้สำรวจ ด้วยตนเอง จากนั้นครูให้นักเรียนแต่ละกลุ่มนำเสนอข้อมูลและตอบคำถามที่ได้ถามก่อนที่จะสำรวจ หน้าชั้นเรียน

A) "เป็น, เพราะนักเรียนได้ศึกษาเรียนรู้และปฏิบัติด้วยตนเอง"

B) "เป็นการสอนแบบสืบเสาะหาความรู้ เพราะผู้เรียนต้องมีการสำรวจและเชื่อมโยงจากสิ่งที่สังเกตเข้ากับความรู้ทางวิทยาศาสตร์"

C) " ไม่เป็น เพราะสถานการณ์การสอนนี้ไม่มีขั้นสรุป"

English version

Item 3: A teacher started teaching on the topic of plants characteristics by asking students that "Are there any characteristics of the trees of the garden in our school that are the same or different? Can you group the trees into groups, how?" Then teacher assigns students to survey the trees in the garden by groups, for 20 minutes with necessary survey equipment. The teacher let students design a notetaking and draw a picture representing the characteristics of each tree that they explore. Then, the teacher asks students of each group to present their data and answers the question that he/she have asked before starting the survey activity in front of the class.

A) " Yes, because students learn and practice by themselves "

B) "It is an inquiry teaching method because the learner must explore their surroundings and connect to science knowledge."

C) " No, because this teaching scenario is lack of a conclusion step."

Figure 1. Example of analysing 5 responses (A-C) in the questionnaire (item 3) used for measuring teachers' understanding of inquiry-based teaching.

Assessing teachers' use of inquiry based-teaching

For the self-evaluation questionnaires, teachers' frequency of using factor solutions for Inquiry Strategies Scale (IS) (Lakin & Wallace, 2015) was evaluated by determining activity levels (all activities =5, often=4, sometimes=3, rarely =2 and never=1). The average and standard deviation of the frequency was represented for each item. Relationships between teachers' understanding of inquiry-based teaching and teachers' frequency of using inquiry-based strategies, and Pearson correlation were performed using SPSS 16.0 software.

Results

Teachers' understanding about inquiry-based teaching in terms of levels of inquiry and the essential features of inquiry

As illustrated in Figures 2, 3 and 4, the percentages of participants classified into the *understanding* group for each item were between 0 and 42.1%, which was less than the percentage of participants classified into the partial understanding group for all items. Notably, 42.1% of the participants were classified in the understanding group for item 7, while none of the responses were classified into the *understanding* group for items 5 and 8. Seven items – 6, 7, 8, 10, 11, 12 and 14 – had highest percentage of participants classified into the *partial understanding* group. Interestingly, for each item, between 2.6 and 94.7% of participants were classified into the *incorrect understanding* group. For items 1, 2, 3, 5, 13, 15, 17 and 18, more than 50% of participants placed in this group. Only item 4 had the same percentages of participants in the *partial* and *incorrect understanding* groups. Eleven items – 1, 2, 3, 4, 5, 9, 13, 15, 16, 17 and 18 – had highest percentage of participants classified into the *incorrect understanding* group.

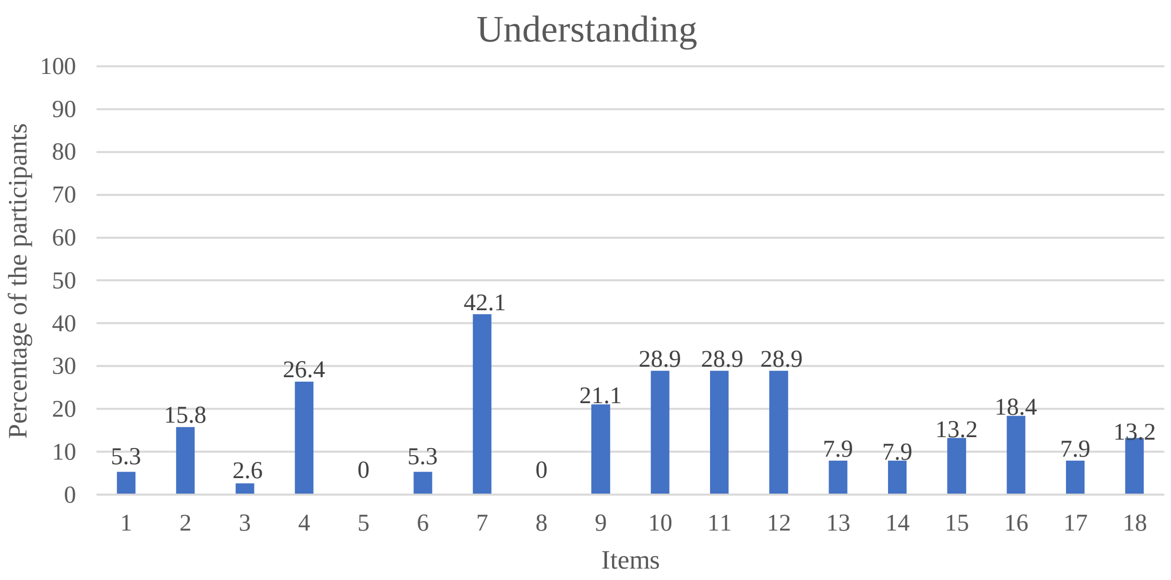

Figure 2. Percentage of participants classified into the *understanding* group.

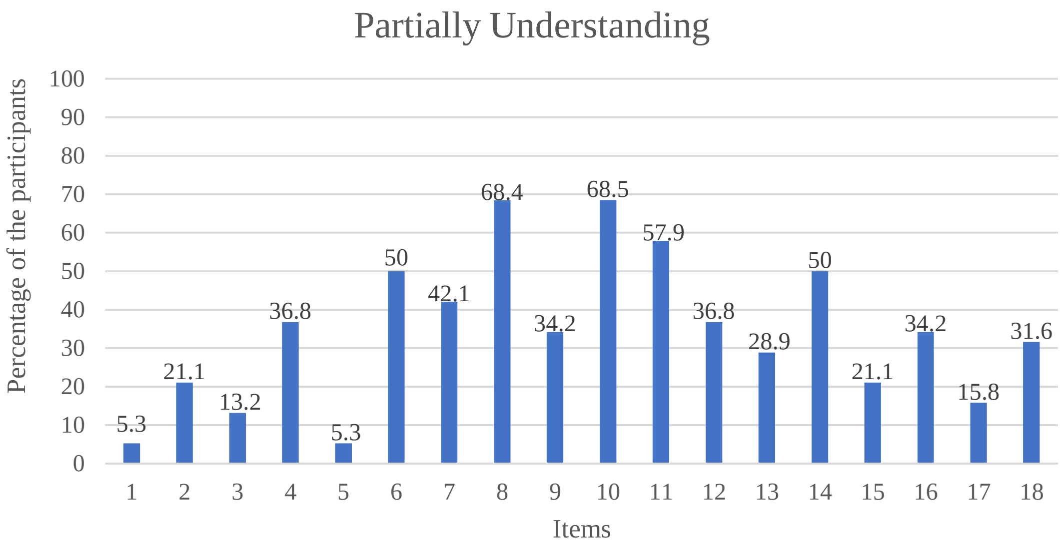

Figure 3. Percentage of participants classified into the *partially understanding* group.

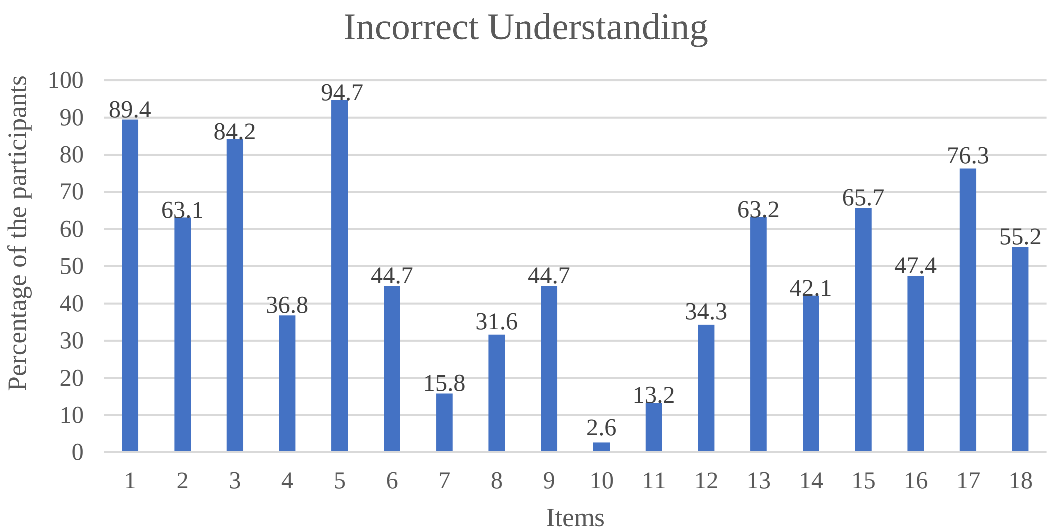

Figure 4. Percentage of participants classified into the *incorrect understanding* group.

As shown in Table 3, none of the participants referred to the five essential features of inquiry-based teaching, only one teacher (3%) referred to some levels of inquiry-based teaching, most (48%) mentioned roles of teachers and students, 26% referred to science process skills including observing qualities, measuring quantities, sorting/classifying, inferring, predicting, experimenting, and communicating, and 16% referred to steps of the 5Es learning cycles. The misconceptions about inquiry-based teaching detected from this study are: 1) students must construct knowledge in the class by themselves without guidance from teachers (48%); 2) students must be engaged to discover new knowledge without confirming the knowledge that scientists have previously discovered (30%); 3) students always do the experiment (37%), explore data or knowledge in a library (13%) for an inquiry-based teaching class; and 4) inquiry-based teaching is only the 5Es learning cycle (16%).

Table 3. Teachers' understanding and misconceptions about inquiry-based teaching.

		Percentage of all (N=38)
Understanding	Referring to 5 essential features of inquiry-based teaching when they were asked to indicate which situations were inquiry-based teaching.	-
	Using types and levels of inquiry-based teaching for indicating which situations are inquiry-based teaching.	3%
	Considering roles of teachers and students in a class for indicating which situations are inquiry-based teaching.	48%
	Referring to science process skills, including observing qualities, measuring quantities, sorting/classifying, inferring, predicting, experimenting, and communicating.	26%
	Using only the steps of 5Es learning cycles to consider which situations are inquiry-based teaching.	16%
Misconceptions	Inquiry-based teaching, 'students must construct knowledge in the class by themselves without guiding from teachers".	48%
	Inquiry-based teaching, students must be engaged to discover new knowledge without confirming the knowledge that scientists have previously discovered.	30%
	Students always do the experiment in an inquiry-based teaching class.	37%
	Inquiry-based-teaching, students always explore data or knowledge in a library.	13%
	Inquiry-based teaching is only 5Es learning cycles.	16%

Teachers' frequency of using inquiry-based strategies

As shown in Table 4, teachers' average frequency of use of inquiry-based strategies was 3.72 (SD = 0.60). Considering each item, the results indicate that the teachers always used the activities that allowed students to discuss explanations in answering questions or how to solve science problems (= 4.03, SD = 0.72). This is followed by activities that provide an opportunity for students to explain scientific principles to teachers or other learners at a higher level (=3.87, SD = 0.81). Conversely, the teachers sometimes used activities that allowed students to spend time in creating science projects or scientific experiments for many days (= 3.32, SD = 0.99). Teachers' average frequency of non-inquiry-based strategies use was 3.17 (SD. = 0.62).

When considering each individual strategy, the participants sometimes used activities that included listening to lectures on science ($\bar{x}$ = 3.45, SD = 0.76), memorising knowledge from textbooks or facts to take tests, or tests while studying ($\bar{x}$ = 3.05, SD. = 0.84), and recording messages or problems from the supervision sign are at a moderate level ($\bar{x}$ = 3.00, SD = 0.93), respectively. As illustrated in Figure 5, there are eight strategies that most participants included in their responses. The frequency for these strategies was '*often*', except for strategies 3, 6 and 10, which had the largest percentage of participants responding '*sometimes*'. Interestingly, they were the participants who used inquiry-based strategies for all activities in every item, but they were a smaller percentage than the group of participants who '*often*' use inquiry-based strategies. In addition, there were factor solutions of IS scale that the participants rarely use in a class (items 3, 4, 5, 6, 7, 10 and 11). Two factor solutions (items 3 and 9) were not used by 2.6% of the participants.

Table 4. Average and standard deviation of teachers' frequency of use of inquiry and non-inquiry-based strategies.

	Strategies	Average	SD.
(Inquiry strategies)	1. Participate in small groups to make sense of science	3.84	0.72
	2. Give an explanation about how they solved a science problem or designed an experiment	3.84	0.68
	3. Use technology (e.g., probes, cameras) to learn science	3.47	1.01
	4. Explain concepts to me or to another student	3.87	0.81
	5. Design and conduct their own experiment or scientific investigation	3.71	0.84
	6. Do science projects or investigations that take several days to complete	3.32	0.99
	7. Apply science situations to life outside of school	3.76	0.82
	8. Discuss alternative explanations for a question or problem	4.03	0.72
	9. Explore questions created by students	3.80	0.81
	10. Analyse data using charts, tables, or graphs	3.47	0.86
	11. Write about the results of scientific investigations	3.76	0.85
	Average	**3.72**	**0.60**
(Non-inquiry strategies)	12. Listen to a lecture about science	3.45	0.76
	13. Copy notes or problems off the board	3.00	0.93
	14. Memorise formulas and facts for a test or quiz	3.05	0.84
	Average	**3.17**	**0.62**

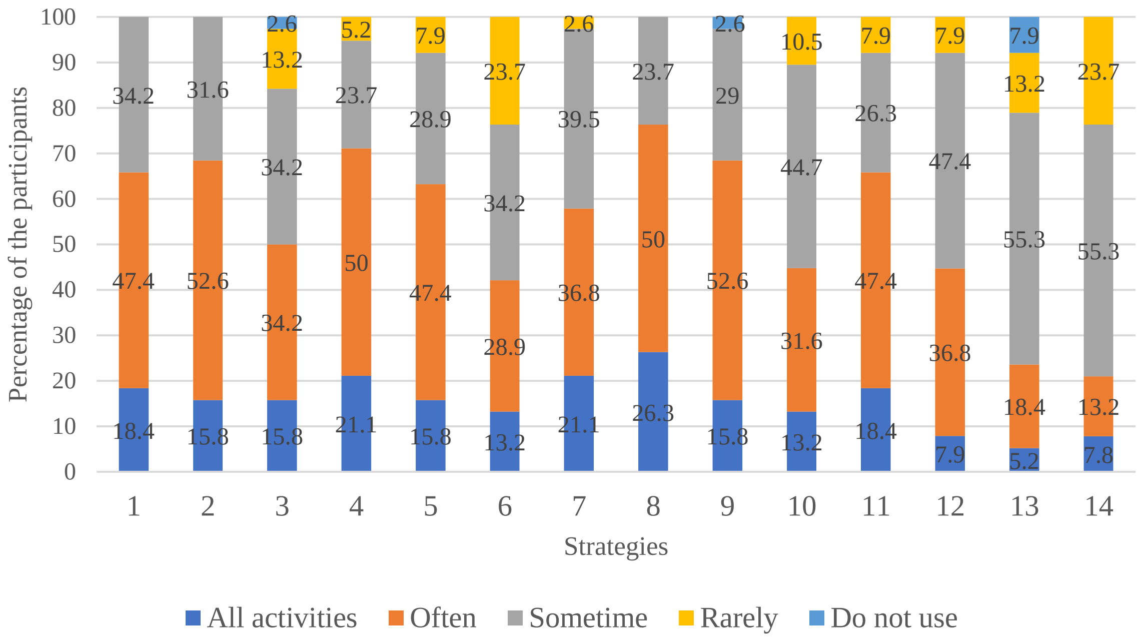

Figure 5. Percentage of participants classified by determining frequency levels (all activities, often, sometimes, rarely, do not use) of use of inquiry and non-inquiry-based strategies, strategies 1–11 and 12–14, respectively.

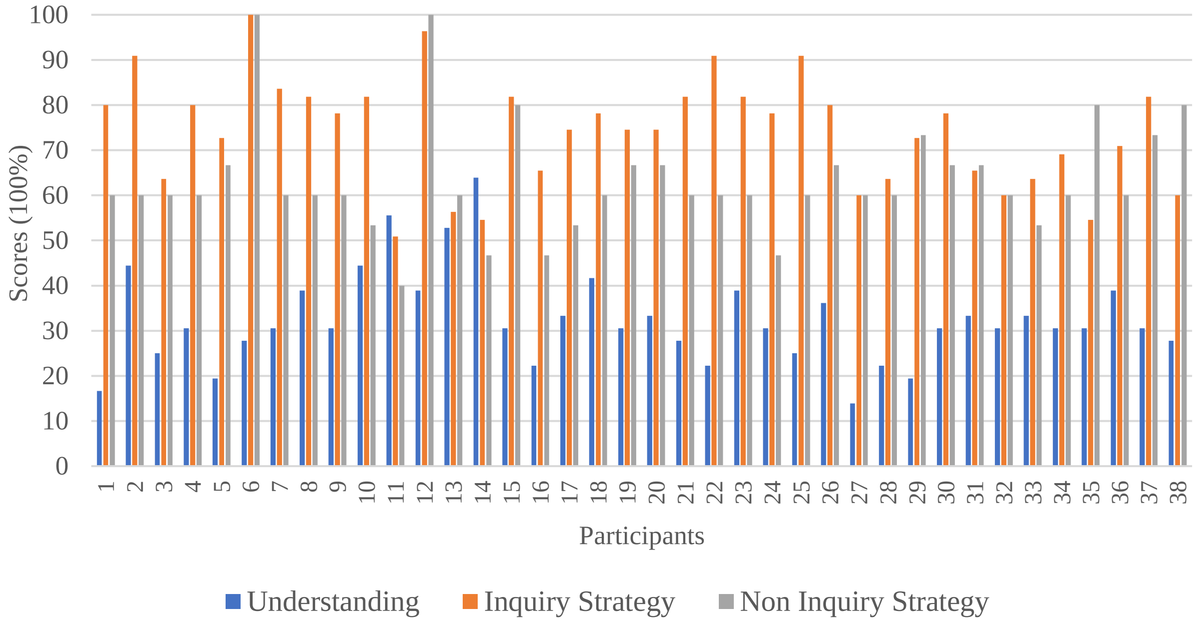

Figure 6. The scores (percentage) for understanding the essential features of inquiry-based teaching, and teachers' frequency of use of inquiry and non-inquiry strategies.

As illustrated in Figure 6, the scores for teachers' understanding of inquiry-based teaching and teachers' frequency of use of inquiry and non inquiry-based strategies were calculated as a percentage of all total scores from each questionnaire. We found that most *understanding of inquiry-based teaching* scores were less than the scores for teachers' frequency of use of inquiry-based strategies, except in the cases of participants 11 and 14 who had understandings of inquiry-based teaching scores greater than their scores for frequency of inquiry-based strategies use.

Table 5. Comparison of relationship between teachers' understanding of inquiry-based teaching and teachers' frequency of use of inquiry and non-inquiry-based strategies.

Correlations

		Teachers' understandings of essential features of inquiry-based teaching	Teachers' frequency of use of inquiry-based strategies	Teachers' frequency of use of non-inquiry-based strategies
Teachers' understandings of inquiry-based teaching	Pearson Correlation	1	-.189	-.250
	Sig. (2 tailed)		.255	.129
	N	38	38	38
Teachers' frequency of use of inquiry-based strategies	Pearson Correlation	-.189	1	.412*
	Sig. (2 tailed)	.255		.010
	N	38	38	38
Teachers' frequency of use of non-inquiry-based strategies	Pearson Correlation	250	.412*	1
	Sig. (2 tailed)	.129	.010	
	N	38	38	38

As outlined in Table 5, the Pearson correlation found that the significant level was 0.255, which is greater than 0.05 (0.255 <0.05); therefore, teachers' understanding of inquiry-based teaching and teachers' frequency of using inquiry-based strategies was not related. Considering the correlation coefficient (r), we found that the value -0.189 indicated that if teachers' understanding of inquiry was high, the teachers' frequency of using inquiry-based strategies was low. The teachers' frequency of inquiry-based strategies use was identified at the high level. The teachers' most frequently used inquiry-based strategy was *an activity that gave students an opportunity to discuss explanations in answering questions or how to solve scientific problems at a high level*. Next was *an activity that gave students an opportunity to explain scientific principles to the teacher or other learners at a high level*. The teachers' least used strategy was *activities that allow students to take time to complete science projects or scientific experiments for many days*, which was at a medium level.

Discussion

As shown in Figure 4, most participants (greater than 50%) are classified into the *incorrect understanding* groups (items 1, 2, 3, 5, 13, 15, 17, 18). Most of them could not identify teaching scenarios that *lack giving priority to evidence*, the 2nd feature (item 15, 18); *formulating explanations from evidence*, the 3rd feature (item 5); *evaluating explanations in light of alternative explanations*, the 4th feature (item 1, 3); and *communicating and justifying*, the 5th features (item 17). This relates to Kang et al.'s (2008) report that teachers rarely mentioned the 4th feature, and the 5th features when they were asked how to modify a lesson plan to be more inquiry- oriented, also consistent with Seung et al. (2014). However, half of the teachers could identify the scenarios that lack the 1st feature (item 6, 14), implying that *engaging in scientifically oriented questions* is an important feature they recognise in teaching science. Moreover, although the teaching scenarios in items 2 and 13 refer to all of the inquiry features, they still resulted in the most *incorrect understanding* score, in terms of none of the participants having referred to the five essential features. This suggests that the teachers lack understanding in the essential features of inquiry-based science teaching.

A general misconception detected from this study is that '*students always do the experiment in a class, supported by a previous study*' (Zhang & Boqin, 2015). However, the dominant misconceptions found in this study are related to our preliminary work, such as '*inquiry-based science teaching is only 5Es learning cycles*', '*students must construct knowledge in the class by themselves without guidance from teachers*', '*students must be engaged to discover new knowledge without confirming the knowledge that scientists have previously discovered*', and '*students always explore data or knowledge in a library*', which are critical misconceptions about inquiry-based science teaching that need to be changed (Luecha & Kaewkhong, 2018). We suggest that providing teachers with the opportunities to gain experience with scientific inquiry may help them to have a better understanding of inquiry-based teaching (Ladachart, 2020).

From the results, teachers' average frequency of using inquiry and non-inquiry-based strategies are at similar levels, 3.72 and 3.17, respectively. In addition, their understanding of inquiry-based teaching is not correlated with their self-evaluation regarding inquiry-based strategies, the teachers seem to rate their knowledge and beliefs in inquiry more highly than they were rated in practice, in line with previous studies (Lee et al., 2004; Kaya et al., 2020).

In summary, this study makes significant contributions by surveying teachers' understanding about inquiry-based science teaching in the Thai context, which is quite critical. The elementary science teachers need effective training to develop their teaching of science based on inquiry.

Limitation

The main limitation of this study is the fact that all the data were collected via self-evaluation from each teacher. Actual observations, or some qualitative data from the teachers, would help to triangulate the findings.

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