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Research Article

Effects of a Teacher Development Program on Science Teachers' Conceptions of Inquiry-based Teaching and Teaching Quality

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ABSTRACT

This research explores the conceptual change of inquiry-based teaching and the teaching quality of 12 Thai elementary science teachers who participated in a teacher professional development program. We developed the teacher professional development program focusing on helping teachers understand how to teach science using inquiry-based methods. The 12 volunteer Thai elementary science teachers were asked to participate in the program which consisted of 15 activities based on the five essential features of inquiry teaching. Each activity had a specific objective, the teachers were trained by doing activities designed by considering the five essential features of inquiry teaching. The teachers 'conceptions of inquiry-based teaching were investigated at the beginning and finishing of the workshop by 18 open-ended questions on teaching scenarios developed by researchers. Besides, their lesson plans and teaching video clips were also determined with the Science Teacher Inquiry Rubric (STIR) to indicate teaching quality and level of inquiry. From the results, we found that teachers' conceptions of inquiry-based teaching were significantly correlated to their teaching quality.

Keywords: professional development program, conceptions, inquiry-based teaching, teaching quality

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Introduction

From the previous studies, inquiry-based teaching is an important method that supports learning and teaching science [1, 2]. In Thailand, inquiry-based teaching is promoted by the Institute for the Promotion of Teaching Science and Technology (IPST) [3] widely. Inquiry-based teaching is the method formed by constructivism theory, in which students are required to search, explore, investigate, and research through different methods until they can understand and perceive that knowledge in a way that they can store in the long-term brain. Inquiry-based learning can be applied in daily life [4], the previous studies [5, 6] mentioned that inquiry generated by the student's experience and was a key strategy in teaching science. According to the previous studies, the five essential features of inquiry were identified by the National Science Education Standards for Science Education [7], as followings: (1) Learner engages in a scientifically oriented question (2) Learner gives priority to evidence in responding to questions (3) Learner formulates explanations from evidence (4) Learner connects explanation to scientific knowledge (5) Learner communicates and justifies explanations, participation in asking questions, gathering, and analyzing information generated from the survey, creating an explanation and review of concepts, and communicating the results. Besides, the four levels of inquiry-based teaching were classified by the Institute for the Promotion of Teaching Science and Technology (IPST) [8] which correspond to [9] and [10] as follows: confirmed inquiry, structured inquiry, guided inquiry, and open inquiry. Each level of inquiry-based teaching can represent the roles of both teachers and students in a class, it reflects how suitable teachers design teaching activities and facilitate students to understand scientific concepts. For inquiry-based teaching, teachers have to realize that students have different readiness and abilities [11]. To enhance students to learn science effectively and have positive attitudes towards science, the learning activities should be designed by determining the levels and five essential features of inquiry-based teaching [12].

The previous studies indicated that most science teachers tend to teach in the way that they think, which did not have the clarity of inquiry-based teaching and learning [13, 14]. Although the essential features and levels of inquiry-based teaching have been widely used as a framework to help teachers understand and enact inquiry-based instruction in science classrooms [12, 15], the previous study reported that teachers have different conceptions about the meaning of inquiry; for example, teachers may believe that they practice inquiry by asking questions and then pointing the way to answers, teachers may feel that the practice of inquiry is accomplished by having students answer long, open-ended questions [16]. Therefore, indicating a common misunderstanding about inquiry-based teaching needs to be addressed [17]. The previous studies revealed that a few teachers understood what inquiry-based teaching was, and many science teachers lacked experience and pedagogical knowledge of inquiry-based teaching [18, 19]. They tend to organize laboratory experiments for their students in a format reflecting the experimental steps; the fact that their students may already know the answers or results of the experiment may adversely affect the effectiveness of inquiry-based teaching. In Thailand, many problems arise from teachers who teach science by lecturing mainly, rather than allowing students to practice science process skills [20], teachers' designing learning activities did not encourage learners to

think critically [21]. In addition, teachers' content knowledge affects what teachers teach and how they teach directly which represented the teaching quality of each teacher [22, 23]. For a primary school level, elementary school teachers are required to have basic scientific knowledge and skills [24] to foster children's curiosity, encourage them to explore their surroundings, and develop their knowledge that is useful for everyday life [25]. Teachers play an important role in teaching and develop students' attitudes toward science learning [26] by considering the knowledge of the nature of science [27].

A Professional Development Program (PD) may be one of a suitable process used to rapidly change teachers' conceptions especially scientific and teaching conceptions. Most teacher professional programs were designed in order to develop knowledge and teaching ability [27]. The programs should meet different needs such as content knowledge, scientific knowledge, and teaching content knowledge [7]. The common core elements of a high-quality and effective program: (1) Focus on a specific topic; (2) An opportunity to experience hands-on activities through active learning; (3) Clear integration into the school curriculum and classroom practice; (4) A sufficient period of time; and (5) Participation [28, 29]. Khvilon and Patru [30] emphasize that the scientific experience presented in an informal environment not only fosters the professional development of teachers in content knowledge, but also provides access to resources. It also shows that such programs increase the efficiency of knowledge, improve scientific content, develop teachers' ability to connect natural science content with formal guidance, and assist in recommending resources for the classroom [31, 32]. For Thailand, a PD Program is the effective method used to develop several skills of Thai science teachers such as critical thinking and problem-solving skills [33, 34], understanding of the nature of science [35], pedagogical reasoning skills [36] and inquiry-based teaching [37, 38]. Particularly of inquiry-based teaching, the previous study recommends that Thai elementary science teacher may need a PD Program to develop their conceptions of inquiry-based teaching [39], therefore, this currents study aims to presents the effects of a teacher development program on science teachers' conceptions of inquiry-based teaching and teaching quality.

From the literature reviews, teachers' conceptions of inquiry-based teaching are necessary to be corrected and trained to use in a suitable way. A PD Program designed by determining by the levels and essential features of inquiry-based teaching may encourage teachers to have better conceptions of inquiry-based teaching and teaching quality, respectively. The research questions this study addresses are: (1) how do teacher professional development programs affect teachers' conceptions of inquiry-based teaching? (2) how do a teacher professional development programs affect teachers' teaching quality?

The purposes of this study are to explore effects of a teacher development program on Thai elementary school science teachers' conceptions of inquiry-based teaching and teaching quality.

Methods

Participants

Participants consisted of 12 in-service Thai elementary school science teachers (40% female and 60% male) who were under the Chiang Mai Primary Education Service Area Office 1, Academic Year 2020. The teachers were selected by purposive sampling according to convenience, they were contacted via phone call to solicit the participation in the workshops on inquiry-based teaching professional development program. They voluntarily responded to the call to complete the online questionnaires about their conceptions of inquiry-based-teaching and participate the professional development program during January 2021. Besides, they were asked to use the lesson plans they designed in the workshop by determining the levels and essential features of inquiry-based teaching in their classes, their teaching video clip and the lesson plans were analyzed for indicating their teaching quality.

Data collection

A mixed method design was used for collecting data of this study. The inquiry-based teaching professional development program used in this study was developed by considering the misconceptions of inquiry-based teaching which was case study research of Thailand [39], there were 15 activities validated by a focus group method of 13 experts in science teaching of Thailand. The consistency of objectives, content accuracy and consistency of inquiry-based teaching concepts were determined and discussed. The final version of the professional development program was trialed with two non-participants elementary school science teachers for a pilot study to determine the suitability of contents, the sequence of activities, time for activities organization, media, equipment, and obstacles that may arise during the training of the professional development program. All information and suggestions obtained from the steps mentioned above were used to improve and correct the activities. The examples of the activities are shown in Table 1.

Table 1 The examples of activities used in the inquiry-based teaching professional development program

Item	Activity	The essential features of inquiry
1. Paper shoot	The participants are asked to write their answers to the questions as shown in followings. 1. What is the first feeling when an invitation letter/command is received? 2. When I came into the training room, what was the first feeling? 3. What to expect in today's training session Then, throw them away, keep the paper randomly, read the answer and share with other participants.	Learner engages in a scientifically oriented questions

Table 1 ***(cont.)*** The examples of activities used in the inquiry-based teaching professional development program

Item	Activity	The essential features of inquiry
2. Which one?	The participants are asked to answer the question about teachers' behaviors, how they can categorized characteristics of learning style of 5 students.	
3. Three words	The participants are asked to represent 3 words for inquiry-based teaching	
4. Group Learning Activities	The participants were divided into groups and encouraged to play a role as students and teachers according to each teaching scenario. Scenario 1: Onions and Coriander (Confirmation inquiry) Scenario 2: Acid or Base (Structure inquiry) Scenario 3: Plasticine Bridge (Guided inquiry) Scenario 4 PM 2.5 (Open inquiry) After that, they were asked to analyse and discuss the roles of teachers and students in each teaching scenario, they were asked to answer which teaching scenario is suitable for their class and described the reasons.	Learner gives priority to evidence in responding to questions Learner formulates explanations from evidence

The questionnaire used to explore teachers' conceptions of inquiry-based teaching in this study were developed by the researchers consists of 18 open-ended questions designed with consideration of the essential features and levels of inquiry-based teaching [7, 40], as described in Table 2. The index of item objective congruence (IOC) and content validity of the questionnaires were between 0.67 and 1.0, determined by five experts in science teaching, which is higher than 0.5. The questionnaires were trialed for a pilot study with 174 non-sample groups of science teachers to determine discrimination, which was in the range between 0.78 and 0.8. The reliability of the questionnaires, determined using Cronbach's alpha, was 0.82. All teachers were asked to complete the questionnaire before and after participating the professional development program.

Table 2 Items used for measuring teachers' conceptions 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)

Table 2 ***(cont.)*** Items used for measuring teachers' conceptions 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
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)

All teachers were asked to send the lesson plan used in the class via e-mail before participating in the professional development program, during, they were trained and asked to design the lesson plan based on inquiry-based teaching, during the professional development program. Then all lesson plans would be considered and suggested by the researchers to improve the activities in order to be a higher level of inquiry-based teaching for a final version, the 3 version of lesson plans, before, during and after the workshop, were considered levels of inquiry-based teaching. Lastly, the teachers were asked to use the final lesson plan in their class, the teaching video clips were recorded and sent to the researchers for considering teaching quality.

Data analysis

Approaching teachers' conceptions of inquiry-based teaching, their responses to the questionnaires were categorized into groups, using the criteria applied from the previous study [41], 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 plant characteristics by asking students "Are there any characteristics of the trees in the garden in our school that are the same or different? Can you group the trees into groups, and how?" Then the teacher assigns students to survey the trees in the garden in groups, for 20 minutes with the necessary exploration equipment. The teacher let students design their note-taking 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 2, 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 1 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 pre- and post- scores of conceptual understandings were compared by using t-test method to represent a significant of statistic.

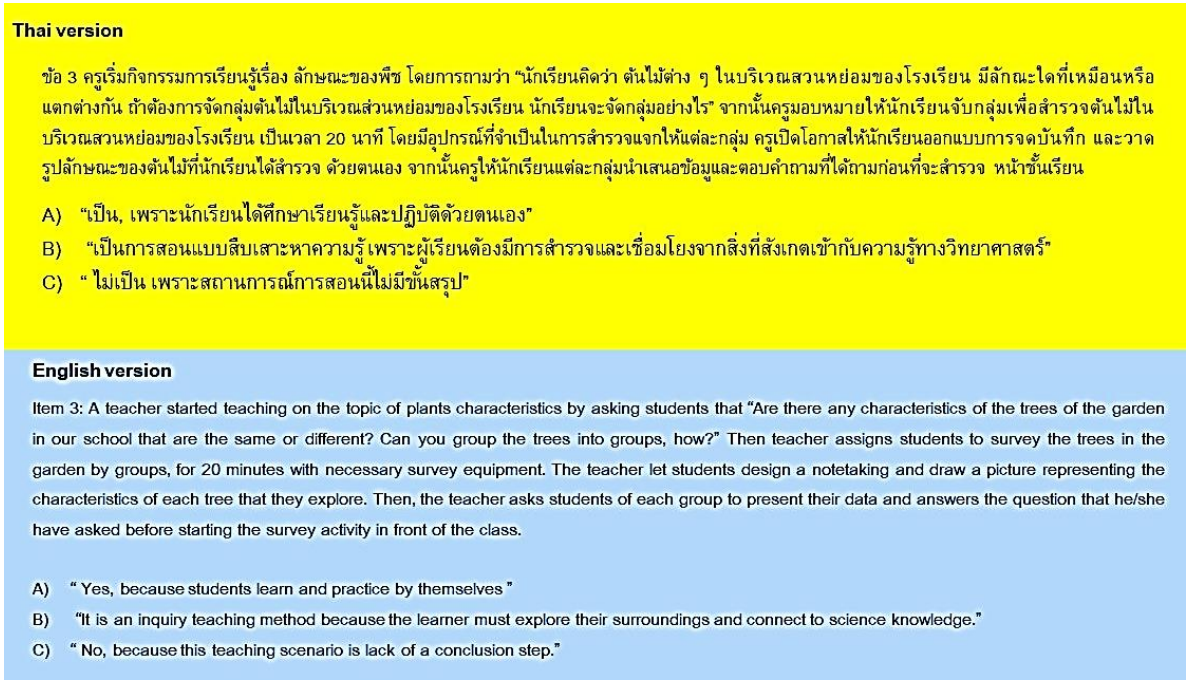

Figure 1 Example of analysing 5 responses (A-C) in the questionnaire (item 3) used for measuring teachers’ conceptions of inquiry-based teaching.

The last version of lesson plans was considered with the Science Teacher Inquiry Rubric (STIR) [42], described in Figure 2. Consequently, each rubric of (STIR) was transformed to the essential features of inquiry- based teaching [7] appeared in the lesson plan identified with a consensus of three researchers.

Learner Centered ⟷ Teacher Centered

Learners are engaged by scientifically oriented questions.					
Teacher provides an opportunity for learners to engage with a scientifically oriented question.	Learner is prompted to formulate own questions or hypothesis to be tested. ☐	Teacher suggests topic areas or provides samples to help learners formulate own questions or hypothesis. ☐	Teacher offers learners lists of questions or hypotheses from which to select. ☐	Teacher provides learners with specific stated (or implied) questions or hypotheses to be investigated. ☐	No evidence observed. ☐
Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.					
Teacher engages learners in planning investigations to gather evidence in response to questions.	Learners develop procedures and protocols to independently plan and conduct a full investigation. ☐	Teacher encourages learners to plan and conduct a full investigation, providing support and scaffolding with making decisions. ☐	Teacher provides guidelines for learners to plan and conduct part of an investigation. Some choices are made by the learners. ☐	Teacher provides the procedures and protocols for the students to conduct the investigation. ☐	No evidence observed. ☐
Teacher helps learners give priority to evidence which allows them to draw conclusions and/ or develop and evaluate explanations that address scientifically oriented questions.	Learners determine what constitutes evidence and develop procedures and protocols for gathering and analyzing relevant data (as appropriate). ☐	Teacher directs learners to collect certain data or only provides portion of needed data. Often provides protocols for data collection. ☐	Teacher provides data and asks learners to analyze. ☐	Teacher provides data and gives specific direction on how data is to be analyzed. ☐	No evidence observed. ☐

Figure 2 The Science Teacher Inquiry Rubric (STIR).

Learners formulate explanations and conclusions from evidence to address scientifically oriented questions.					
Learners formulate conclusions and/or explanations from evidence to address scientifically oriented questions.	Learners are prompted to analyze evidence (often in the form of data) and formulate their own conclusions/explanations. ☐	Teacher prompts learners to think about how analyzed evidence leads to conclusions/explanations, but does not cite specific evidence. ☐	Teacher directs learners' attention (often through questions) to specific pieces of analyzed evidence (often in the form of data) to draw conclusions and/or formulate explanations. ☐	Teacher directs learners' attention (often through questions) to specific pieces of analyzed evidence (often in the form of data) to lead learners to predetermined correct conclusions/explanations (verification). ☐	No evidence observed. ☐
Learners evaluate the explanations in light of alternative explanations, particularly those reflecting scientific understanding.					
Learners evaluate their conclusions and/or explanations in light of alternative conclusions/ explanations, particularly those reflecting scientific understanding.	Learner is prompted to examine other resources and make connections and/or explanations independently. ☐	Teacher provides resources to relevant scientific knowledge that may help identify alternative conclusions and/or explanations. Teacher may or may not direct learners to examine these resources, however. ☐	Teacher does not provide resources to relevant scientific knowledge to help learners formulate alternative conclusions and/or explanations. Instead, the teacher identifies related scientific knowledge that could lead to such alternatives, or suggests possible connections to such alternatives. ☐	Teacher explicitly states specific connections to alternative conclusions and/or explanations, but does not provide resources. ☐	No evidence observed. ☐
Learners communicate and justify their proposed explanations.					
Learners communicate and justify their proposed conclusions and/or explanations.	Learners specify content and layout to be used to communicate and justify their conclusions and explanations. ☐	Teacher talks about how to improve communication, but does not suggest content or layout. ☐	Teacher provides possible content to include and/or layout that might be used. ☐	Teacher specifies content and/or layout to be used. ☐	No evidence observed. ☐

Figure 2 (cont.) The Science Teacher Inquiry Rubric (STIR).

The last version of lesson plans was considered with the Science Teacher Inquiry Rubric (STIR) [42], described in Figure 2. Consequently, each rubric of (STIR) was transformed to the essential features of inquiry- based teaching [7] appeared in the lesson plan identified with a consensus of three researchers.

The teaching video clips of each teacher were considered with the criteria of [43], as shown in Table 3. Besides, the role of teachers and students were determined to identified levels and quality of inquiry-based teaching. Using the following labels: Level 0 (No inquiry), Level 1 (Little inquiry), Level 2 (Limited, typically short-term inquiry), Level 3 (Some sustained practice-level inquiry), and Level 4 (Iterative, recursive inquiry into practice).

Table 3 The criteria used to measure levels and quality of inquiry-based teaching [43].

Level	Label of teaching quality	Criteria
0	No inquiry	No goals identified or no reference of working toward goals.
1	Little inquiry	Set goals, but no reference of working toward goals that had been set. No evidence of planning, reflecting, monitoring or making alterations.
2	Limited, typically short-term inquiry	Mention of goals, but limited examples of working toward goals. Limited evidence of planning, reflecting or monitoring. Short-term example of alteration of practice related to goals and plans.
3	Some sustained practice-level inquiry	Mention of goals with several segmented examples of lessons working toward goals. Evidence of some ongoing planning, and some evidence of reflecting and monitoring. Example of alteration of practice due to knowledge emerging from inquiry.
4	Iterative, recursive inquiry into practice	Clearly defined goals with multiple elaborations including several examples of lessons and other efforts to work toward goals. Indications of continuous programming toward goals. Evidence of purposeful planning in either lessons or program goals. Evidence of reflection on progress toward goals either during and/or after process. Multiple examples of alteration of practice due to knowledge derived through inquiry.

Both lesson plan and teaching video clips were considered together, as shown for instant in Table 4. The results represent that the lesson plan of the first participant was designed according to all 5 essential features of inquiry-based teaching and categorized into confirmation inquiry because most activities was confirming a principle through an activity by students when the results are known in advance. However, the teaching quality of the first participant was categorized into Limited, typically short-term inquiry. While the lesson plan of the second and third participants represent that there were all essential features of inquiry-based teaching, but the 1^{st}, 2^{nd}, 4^{th}, and 5^{th} essential features were classified into structured inquiry level. The teaching quality of the second and third participants were different, Some sustained practice-level inquiry and Limited, typically short-term inquiry, respectively.

Table 4 An example of Criteria of the Science Teacher Inquiry Rubric (STIR) applied for measuring level of inquiry-based teaching and teaching quality [42].

Participants	Assessing the essential features of inquiry-based teaching appeared in a lesson plan					Inquiry-based teaching levels and teaching quality determined from the teaching video clips
	The 1st feature	The 2nd feature	The 3rd feature	The 4th feature	The 5th feature	
1	✓*	✓*	✓*	✓*	✓*	Limited, Typically Short-term Inquiry
2	✓*	✓*	✓**	✓*	✓*	Some sustained practice-level inquiry
3	✓*	✓*	✓**	✓*	✓*	Limited, Typically Short-term Inquiry

Note: ✘ = It is no inquiry-based teaching

✓ = It is inquiry-based teaching

* = Students confirm a principle through an activity when the results are known in advance (Confirmation inquiry inquiry).

** = Students investigate a teacher-presented question through a prescribed procedure. (Structured inquiry).

***= Students investigate a teacher-presented question using student designed/selected procedures. (Guided inquiry).

**** = Students investigate questions that are student formulated through student designed/selected procedure (Opened inquiry).

Results and Discussions

As shown in Figure 3, the results revealed that most participants' response were classified into Incorrect Understanding (I) which was greater than the number of participants classified into Partial Understanding (P) and Understanding (U) before training which is related to the previous study [39]. Additionally, the number of the participants whose answers were classified into Partial Understanding (P) was greater than the number of participants whose answers were classified as "correct," or Understanding (U). After the training, all participants had a higher level of understanding, most participants' responses were classified into Understanding (U), accepted the second participant whose response classified into Partial Understanding (P) equal to Incorrect Understanding (I), as shown in Figure 4. However, the average pre-test and post-test understanding scores are 10.92 and 20.33, respectively, the t value was -11.88 and the Sig. 0.000 which less than 0.05. It means that the pre-test understanding scores differs from the post-test understanding scores significantly. From the results, the teachers' understanding scores of inquiry-based teachings are higher after participating in the teacher professional development program related to the results of previous studies [44-46]. Obviously, all responses of each teacher could not be improved to Understanding (U) group, they were still had some responses classified into Incorrect Understanding (I) and Partial Understanding (P). It is not surprising results for the researchers because each teacher still had some personal limitations for improving themselves to understand inquiry-based teaching [45]. In addition, a personal belief of each teacher which affected to their teaching conceptions were hard to change [47-49]. The conceptions of inquiry-based teaching reported in this current

focused on the essential features of inquiry-based teaching which were different from the previous study focusing on teaching concepts [50], teachers' and student' roles concepts [51].

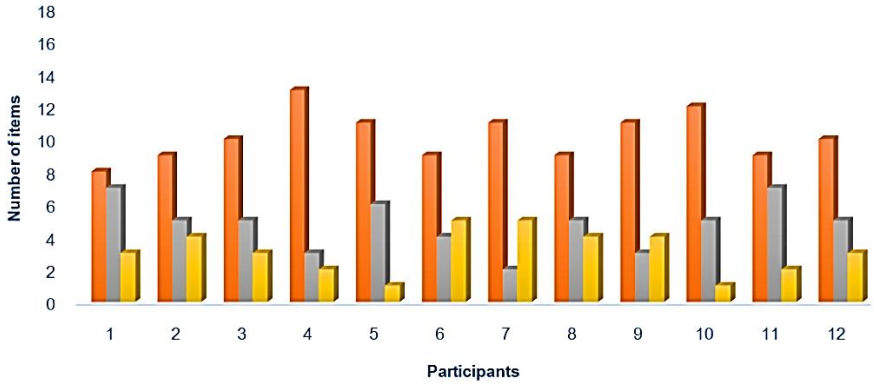

Figure 3 The teachers' pre-test responses of inquiry-based teaching conceptions classified into three conception groups: Incorrect Understanding (I), Partial Understanding (P) and Understanding (U).

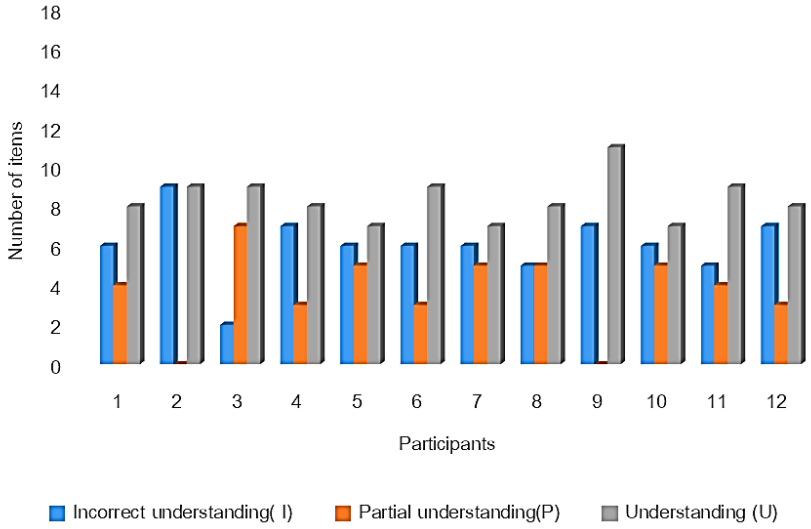

Figure 4 The teachers' post-test responses of inquiry-based teaching conceptions classified into three conception groups: Incorrect Understanding (I), Partial Understanding (P) and Understanding (U).

Table 5 Comparison of understanding scores on five essential features of inquiry-based teaching, before and after training (t-test).

Test	N	Mean	S.D.	t	Sig. (2-Tailed)
Pre	12	2.39	.69	-11.883*	.000
Post	12	1.97	.57		

*.05 level of significance

Table 6 Summary of the results of the assessment of the learning activities based on inquiry of the first sample.

Lesson plans	The essential features of inquiry-based teaching appeared in a lesson plan					The quality of inquiry-based teaching determined from teaching video clip
	The 1st feature	The 2nd feature	The 3rd feature	The 4th feature	The 5th feature	
Before training	✓* = 100% ✓** = 0% ✓*** = 0% ✓**** = 0% ✘ = 0%	✓* = 75.00% ✓** = 8.33% ✓*** = 0% ✓**** = 0% ✘ = 16.67%	✓* = 58.33% ✓** = 25.00% ✓*** = 0% ✓**** = 0% ✘ = 16.67%	✓* = 91.67% ✓** = 0% ✓*** = 0% ✓**** = 0% ✘ = 8.33%	✓* = 41.67% ✓** = 25.00% ✓*** = 0% ✓**** = 0% ✘ = 33.33%	No inquiry 0% Little inquiry 8.33% Limited, Typically Short-term Inquiry 6.67% Some sustained practice-level inquiry 5.00% Iterative, recursive inquiry into practice 0%
During training	✓* = 16.67% ✓** = 58.33% ✓*** = 16.67% ✓**** = 8.33% ✘ = 0%	✓* = 8.33% ✓** = 58.33% ✓*** = 16.67% ✓**** = 16.67% ✘ = 0%	✓* = 3.33% ✓** = 50.00% ✓*** = 8.33% ✓**** = 8.33% ✘ = 0%	✓* = 33.33% ✓** = 25.00% ✓*** = 6.67% ✓**** = 0% ✘ = 25.00%	✓* = 41.67% ✓** = 8.33% ✓*** = 0% ✓**** = 0% ✘ = 50.00%	No inquiry 0% Little inquiry 0% Limited, Typically Short-term Inquiry 16.67% Some sustained practice-level inquiry 33.33% Iterative, recursive inquiry into practice 50.00%
After training	✓* = 0% ✓** = 50.00% ✓*** = 16.67% ✓**** = 33.33% ✘ = 0%	✓* = 8.33% ✓** = 8.33% ✓*** = 33.33% ✓**** = 50.00% ✘ = 0%	✓* = 8.33% ✓** = 16.67% ✓*** = 25.00% ✓**** = 50.00% ✘ = 0%	✓* = 41.67% ✓** = 0% ✓*** = 16.67% ✓**** = 41.67% ✘ = 0%	✓* = 33.33% ✓** = 25.00% ✓*** = 8.33% ✓**** = 25.00% ✘ = 8.33%	No inquiry 0% Little inquiry 0% Limited, Typically Short-term Inquiry 8.33% Some sustained practice-level inquiry 33.33% Iterative, recursive inquiry into practice 58.34%

Note: ✘ = It is no inquiry-based teaching

✓ = It is inquiry-based teaching

* = Students confirm a principle through an activity when the results are known in advance (Confirmation inquiry inquiry).

** = Students investigate a teacher-presented question through a prescribed procedure (Structured inquiry).

*** = Students investigate a teacher-presented question using student designed/selected procedures.(Guided inquiry).

**** = Students investigate questions that are student formulated through student designed/selected procedure (Opened inquiry).

As shown in Table 6, all teachers' lesson plans tend to be designed by considering the essentials features of inquiry-based teaching after training, both percentages of the essential features appeared in the lesson plan and level of teaching quality were increasing. Considering the last version of lesson plan, see after training row of Table 6, we found that the 1st, 2nd, and 3rd features were not only realized by the teachers, but the levels of inquiry levels of those features were increasing to the top levels of inquiry-based teaching, ✓**** = 33.33%, 50.00%, and 50.00%, compared with before and during training. Obviously, the 4th and 5th features were appeared in the lesson plan in the low level of inquiry-based teaching the most, ✓* = 41.67% and 33.33%, respectively. From the results, we can imply that each essential features of inquiry-based teaching are not necessary appeared in the highest level of inquiry-based teaching, they are some obstacles or factors such as a content, teachers' making decision, and beliefs that affect to teacher' teaching sequences [51].

As shown in Table 6, the level of teachers' teaching quality was increasing. However, the Teacher Development Program used in this study could not improve all teachers to be at the highest level of inquiry-based teaching, it may depend on students' learning abilities of each teaching activity, school contexts, science contents and learning objective [51].

Conclusion

It is important to understand how elementary school science teachers' conceptions to inquiry-based teaching because teachers' conceptions effect on their enactment of inquiry in the classroom [18, 19]. Especially in Thailand, the dominant of misconceptions about inquiry-based teaching were revealed [39]. From the results, although we designed and used the Teacher Development Program based on those misconceptions [39] carefully, but conceptions of all teachers could be changed to Understanding (P) conception group. Besides, although all essential features of all teachers were appeared in the lesson plan, but in practice, teachers could not teach science in the highest level of inquiry-based teaching (opened -inquiry). The same as teaching quality, some teachers had understating scores of inquiry-based teaching at a high level, and designed the lesson plan according to all essential features of inquiry-based teaching, in practice, they were some un-controlled factors that affect to their teaching quality such as students' learning ability, school supporting conditions etc. Lastly, teachers' conceptions of inquiry-based teaching, designing a lesson plan, and teaching quality affect to students learning directly, science teachers need to improve their knowledge and teaching skills. In the future works, difficulties of inquiry-based teaching and un-controlled factors that effect to teachers' teaching quality should be discussed and used to improve the Teacher Development Program.

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