

Guidelines for Online PLC with a Lesson Study Approach to Promote STEM Education

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This research aims to provide guidelines for the development of online learning communities for educational institutions in order to promote STEM education. The information presented is based on the study of STEM instruction and a professional learning community (PLC) of 17 primary school teachers from 6 private schools in Thailand. In each school, semi-structured interviews were conducted with teachers responsible for science, mathematics and technology instruction. Technology refers to computer, design and technology courses. In addition, there were 9 expert interviews, including STEM, computer supported collaborative learning (CSCL) and online learning communities, and lesson study concepts. The results of qualitative analysis found that three points about the development of an online PLC in schools to promote STEM teaching should be considered: 1. Individual means a member who will participate in an online PLC, including support staff such as school administrators and technical staff. 2. Information technology refers to a system or tools that can be used as a medium for exchanging knowledge gained from learning among members. 3. Content refers to the structuring of the content displayed in the online learning community and the scheduling of members' activities. Therefore, all these must be considered in the planning of online PLC development that allows members to interact and communicate through the use of CSCL tools, which will lead to the exchange of learning and help among members such as analyzing contents that can be used to link subjects or considering a theme used for STEM instructional design.

Keywords: continuous professional development, lesson study in school, online professional learning community, STEM Education

Education reform in Thailand is very necessary, for which many agencies have given importance and look for modes of development of Thai education, whether it is to lay down educational policies, or education about the ways of teaching and learning to enhance the knowledge and skills of students. STEM education is one way of learning management that will help develop the 21st century skills of students (Kenan Foundation Asia, 2019). Although this learning management approach is widely utilized internationally, in Thailand awareness of STEM education is still limited and diverse (Srikoom, Hanuscin, & Faikhamta, 2017). So it is necessary to develop the professional development about STEM instructional to create understanding and an alternative that teachers will use to develop students. Development of teachers in Thailand has a variety of models, all of which are intended to develop and promote the performance of teachers to be used in classroom teaching (Jamjuree, 2017), such as workshop, self-study, etc. (Tantranont, 2009). However, the implementation of such methods has encountered barriers such as a lack of awareness among teachers, teachers' lack of confidence, practical, and professional skills problems (Dixon, Yssel, McConnell, & Hardin, 2014; Kham-o-part, 2018; Kyndt, Gijbels, Grosemans, & Donche, 2016; Patton, Parker, & Tannehill, 2015). Therefore, one method of professional development is the implementation of

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the PLC as a guideline for continuous professional development through the participation of teachers in the learning community. This may include changes in beliefs and behaviors regarding collaboration to emphasize the achievement of learners (Tam, 2015). These changes were due to the components of the PLC, such as goal setting and teamwork, the effectiveness of the relationship between the teachers, the culture of collaboration and learning activities in the PLC, including various behaviors that the teachers perform social interaction between each other in the PLC that results in teachers learning from their peers. Social interaction in this PLC will be one of the approaches to professional development that corresponds to Vygotsky's sociocultural approach such as study groups, mentoring (Shabani, 2016). This is an example of a group of members that can become a group of practices with lesson study in school. The extent to which the instructor changes while participating in the PLC can be seen in 5 aspects: 1) curriculum; 2) instructional management; 3) learning; 4) teacher's role; and 5) learning to teach. In addition, teacher involvement in the PLC also increases the potential for teaching and learning as reflected in research (Easton, 2012). The results are consistent with Feffer's work in teacher learning within the PLC (Feffer, 2015). He found that the structure of collaborative learning in the PLC was shared knowledge among teachers that the formation of the PLC is sustainable. This corresponds to the research about the structural analysis of factors that influence PLC in Korean elementary schools. The research found that strong and sustainable PLCs are directly related to key factors of promoting learning communities such as school performance, leadership and support for social relationships among school teachers (Oh Song & Choi, 2017). Those factors will encourage the integration of the PLC into the educational environment within the school. One process of building a PLC within the school is through lesson study.

Lesson study, which focuses on actual classroom lessons, is designed to investigate and improve the teaching of a particular topic. Lesson study is one way to establish a continuum for professional development of teachers through the main stages of instructional planning, observation, teaching and reflection. For example, research results from Shúilleabháin (2015), Hird, Larson, Okubo, and Uchino (2014), and Draper (2014) have shown that the concept of lesson study, which is a method of engaging the PLC with activities through collaborative planning, teaching observation, reflection on pedagogy, and focus on learners, positively influenced the professional development of teachers through the exchange of related teaching experiences. This approach to community-based professional learning is one method to achieve professional development, as reported in research by Turner (2015). Turner's study, conducted with a PLC in Arkansas middle school, found that the function of the PLC in the school was related to the culture of collaborative work. The results of this research are consistent with Cheng's study (2017). She created a PLC to integrate information technology into classrooms to assist learners and identified three factors key to successful PLCs: 1) culture of collaboration; 2) data-driven decisions; and 3) supportive leadership impact instruction.

However, the workload assigned to each instructor, whether for teaching or other work within an institution, has become one of the factors interfering the motivation of the PLC integration into institutions. Including, there exist limitations of time, communication methods, and methods of sharing information learned during the process of lesson study; therefore, the development of a PLC requires the use of information technology tools in the areas of communication, exchange of knowledge, joint planning, and other actions among members (Jennifer, 2016). In order to make the activities of the PLC more effective, a tool often used is the CSCL as shown in the Seven Affordances of CSCL: "How Can Collaborative Learning Help?" by Jeong and Hmelo-Silver (2016). This study focused on technology that can be used

for collaborative learning based on the theories of collaborative learning and CSCL. This is consistent with the research on critical factors towards analyzing teachers' presence in online learning communities by Tsiotakis and Jimoyiannis (2016). The conceptual framework of this study is based on the teacher community platform, which consists of four parts: 1) communication area; 2) content sharing area; 3) supportive tools; and 4) community area (Tsiotakis & Jimoyiannis, 2016). In addition, considering the context and environment of activities that are designed for members to perform is important because these activities will affect the intention of the members. As the result of the research that considering the theory of planned behavior helped to understand the context of online environmental community that will cause subjective norms and self-efficacy of members to join and interact with each other. Moreover, it helps to choose the platform and also the CSCL tools (Park & Yang, 2012).

This research paper is part of a project for the development of an online PLC with the concept of lesson study applied in Thai schools to promote STEM education. It is part of the study of primary teachers' opinions on integrated teaching and learning management, STEM instructional design, PLC and lesson study. The research question is "What are the opinions of teachers from private schools about the online professional learning community, lesson study approach, STEM instructional design?". In addition, the inclusion of experts' opinions about the online PLC model, the lesson study approach, and the design of STEM instruction will lead to the development of an online PLC to promote STEM education. A problem with STEM is that teachers in Thailand and many countries do not fully understand it, thus limiting teachers' confidence in it, leading to failure to design effective learning management systems. This is shown in the research of Aregamalage, Hong, and Fang (2017) who discuss the challenges and issues in learning management in light of the view that STEM teachers encountered difficulties in adapting to the integration of reforms in their classrooms. In addition, this view is consistent with the findings of Shernoff, Sinha, Bressler, and Ginsburg (2017), who found that most teachers are believed to be interested in integrated approaches to STEM, but do not believe they are well enough prepared to implement them. Following from these needs and issues, teachers must develop their professional skills through various methods. One way is to integrate them into a PLC with a lesson study approach so that teachers can learn new skills to implement an integrated approach, new knowledge and new curriculum materials (C. C. Lewis, Perry, Friedkin, & Roth, 2012). It also provides a medium for the exchange of learning strategies among teachers across disciplines and teacher collaboration for instruction in STEM focusing on the school context (Slavit, Nelson, & Lesseig, 2016).

Literature Review

Professional learning community is a term used in many fields with many meanings, including in the field of education. Watson (2014) states that "The concept of the professional learning community (PLC) has been embraced widely in schools as a means for teachers to engage in professional development leading to enhanced pupil learning". This is in line with the concept of Dehdary (2017), who also pointed out that the researcher has an added advantage of closing the gap of the PLC to make the community work more effectively. Those involved should consider issues related to the dynamic work context, management policy, and a nexus of focus communities. As in the research results of Damjanovic and Blank (2018), who have conducted studies to emphasize the situated and contextual nature of teachers' professional learning in context. They performed the following activities: observing, recording, interpreting, and sharing, through a variety of media during the session. In Thailand, the context and cultural factors regarding collaboration are quite specific to the aggregation of the PLC. Therefore,

teachers need to be prepared before starting a PLC in order to establish a conducive environment for exchange and collaboration (Sompong, Erawan, & Dharm-tad-sa-na-non, 2015). They state that good practices that help to develop a PLC in schools are a learning organization that is designed by arranging environmental conditions in the school and developing an organizational culture to facilitate learning as well as using school staff in cooperative learning throughout the PLC process. The present research used this principle as a guideline for the integration of teachers by selecting team members who can make decisions collaboratively and lead the team in collective learning. In short, this is a model for promoting cooperation among teachers. The integration of this community can be applied to the integration of teachers from different subject groups in order to promote the STEM teaching and learning as in the document of the National Commission on Teaching & America's Future (2010).

The main components of the PLC are shared vision and values among PLC members, melded together and examining the students' major subjects, inquiring into the teacher's knowledge, leadership and potential of the members (Battersby & Verdi, 2015; Owen, 2014). The implementation of the teachers' PLC is one of the approaches to professional development which affects the knowledge building of members within the PLC (Popp & Goldman, 2016). PLC action can be carried out through a variety of processes and approaches to achieve collaborative learning such as reflection of members' thoughts. The reflection method is continuous learning and is part of the concept of sociocultural theory (Poovey, 2017). One method of bringing reflection to integrate into a PLC that uses the concepts of lesson study to help the instructor avoid obstacles encountered when teaching alone. Teachers who join the group as members of lesson study will continue their professional development, one of which offers an approach consistent with learning theory and empowerment through collaborative learning and the development of a school culture that values shared responsibility and other ideas that revolve around PLC ideas. Members in the PLC are involved in collaborative planning, observation, reflection, and focus on learners (Caena, 2011). This finding is consistent with Catherine C. Lewis (2015), who discussed the Lesson study cycle consisting of- 1) study; 2) planning; 3) doing; 4) reflecting. This cycle has an impact on instruction and changes a teacher's knowledge and leads to improvement in the instructor's ability to design instructional materials focused on learner achievement. In addition to enhancing the efficiency of the online learning community with the lesson study process the PLC should incorporate face-to-face interaction through the application of information and communication technology to encourage members to learn and collaborate through tools that facilitate learning, for example, CSCL (Jeong & Hmelo-Silver, 2016). Technology groups afford learners opportunities such as 1) engaging in a joint task; 2) communication; 3) resource sharing; 4) engagement in productive collaborative learning processes; 5) engagement in co-construction; 6) monitoring and regulating collaborative learning; and 7) building groups and communities. These tools correspond to ideas in the study by Järvelä et al. (2015) who present three models for supporting socially shared regulation of learning: 1) increasing learner awareness of their own and others' learning processes; 2) supporting externalization of one's own and others' learning process and helping to share and interact; and 3) prompting the acquisition and activation of regulatory processes. Based on this literature and research, the present study uses information technology tools to encourage members to conduct activities in an online learning community. The use of ICT tools will be implemented in conjunction with the use of the lesson study concept in educational institutions to combine effective learning and professional development. The ICT tools can assist in developing projects by tracking activities, planning to support collaborative work where members of the group can work both synchronously and non-synchronously. This

approach will lead to an online PLC which combines the lesson study process with the use of information technology tools to support the exchange of knowledge among teachers during the lesson study process in the academy to build understanding about STEM instructional design. This STEM study is an integrated approach to the design of units with a specific interest in combining science, mathematics and technology through an engineering design process that will develop the knowledge base and 21st century skills of learners (Rinke, Gladstone-Brown, Kinlaw, & Cappiello, 2016). The study documents the elements of the online PLC, the process of lesson study and use of ICT tools in the exchange of learning among teachers. It also presents the results of the interview of the opinions of elementary school teachers and various experts. The resulting data are used as guidelines for the development of online PLC in educational institutions as well as the lesson study concept to promote STEM instructional design.

Method

This study used a qualitative research methodology as it helped to understand the real context and thoughts of teachers in primary schools. The method chosen for collecting data was semi-structured interview. This allowed the researcher to know the perception and opinion of the sample. Therefore, this research is to study the state of teaching and learning in six private elementary schools located in Bangkok, Chiang Mai and Ratchaburi, Thailand. All schools were selected by the criteria of their sizes; small, medium and large school which were 1–120, 121–600 and 601+ students (Office of Basic Education Commission (OBEC), Faculty of Economics Thammasat University, & UNICEF Thailand, 2014), respectively. Then, all sample teachers were contacted for an interview.

All schools that have been selected were notified to request an appointment to interview 2-3 teachers of each school. These teachers would be responsible for teaching in science, mathematics and technology related subjects such as computer subjects, information and communication technology subjects, design and technology subjects. In total, 17 teachers were interviewed between late 2017 to first quarter of 2018, with questions related to understanding about STEM instructional design, concept of lesson study and PLC. These samples provided the information that is in the actual context of the school and is responsible for the design of teaching and learning in the related subjects of STEM education. Each interview took about 30-60 minutes and record audio interviews with the recording program together with the notes. Before conducting the interview, the researcher asked for oral consent from the informants, including notification of the purpose of data collection and other data related to the research to the informants, according to the author's training certified by National Research Council of Thailand (NRCT) and Forum for Ethical Review Committee in Thailand (FERCIT), the on-line research ethics training. In addition, 9 experts were interviewed at each site, with the topics of STEM, CSCL, online PLC, and lesson study. These samples are selected by purposive sampling based on their expertise and experience related to the topic that needs information on each side. This is a study of the state of STEM teaching and learning, the study of the elements and the steps of lesson study, and the implementation of an information technology system in support of collaborative learning. The information was analyzed and used as a guideline for the design of the training curriculum, the guideline for the development of the lesson study, and the design and the provision of information technology systems to encourage learners to collaborate. The instrument used in this study was a semi-structured interview, consisting of questions under the research framework which was applied to the selected sample, then that contact and collect the data by interviewing. When the information is collected complete, the data were analysis with

classifying and organizing the data, such as the data coding for the sound from the transcription of the tape. After this is done, the findings were summarized, which was divided into 2 parts.

Part 1: The research framework for studying the state of STEM education and the PLC of primary school teachers in private educational institutions is shown in the figure 1 following diagram.

The conceptual framework for studying the opinions of primary school teachers from private schools as shown in Figure 1, which is used as a guideline for defining questions in a semi-structured interview, which consists of 4 parts: 1) questions about general information of the interviewee; 2) questions about the understanding of STEM instructional design; 3) questions about the understanding of the lesson study approach; and 4) questions about the understanding of OPLC. This research framework was the result of a study of relevant documents and research.

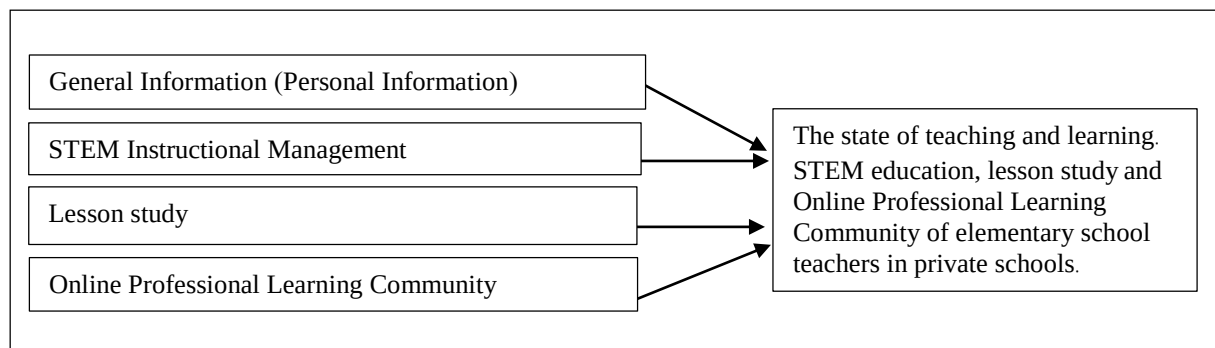


Figure 1. The conceptual framework for the study of the state of STEM education and the PLC of elementary school teachers in private education institutions.

In accordance with the conceptual framework, questions were determined by asking experts to evaluate their content, such as:

1. Teachers' opinions on STEM Instructional Management

Q1: Do you know or understand about STEM teaching and learning? Explain your understanding of this concept.

Q2: From the course you taught, do you think that there is a form of learning management that incorporates the STEM concept in your learning unit?

Q3: Do you know the engineering process or other problem solving process?

2. Teachers' opinions on Lesson Study

Q1: Have you ever heard of or do you know the term “Lesson study”? Explain your understanding of the term.

Q2: What does the term “Lesson study” mean and can you describe it as a process or a procedure?

Q3: Does your school set up a discussion group about classroom management or student learning? Explain your understanding of it.

3. Teachers' opinions on the Online Professional Learning Community

Q1: What do you know about the term “online professional learning community”?

Q2: Do you think that if your school provided an opportunity for group tutors to be a PLC to provide support, shared knowledge, support thinking and working together, would it be a way for you and other teachers to develop professionally? Explain your understanding of this.

Q3: If your school provided an opportunity for instructors in the school to be an online PLC, using information technology tools to support learning together, do you think you would be willing to join the group for the purpose of developing better student achievement? Please provide reasons for your answer.

Part 2: The study of each expert's opinion was based on Figure 1. The conceptual framework of the research led to the examination of the consistency between the questions and the framework by expert assessment of the content of the questions, for example,

1. Experts' opinions on STEM Instructional Management

Q1: In your view, what is the design of STEM Instruction and how is it done?

Q2: How can you evaluate learners who have studied through the STEM unit?

Q3: In your view, what model or teaching methods can be used in a STEM instructional design and why?

2. Experts' opinions on Lesson Study

Q1: What is the composition and procedure of the study lesson?

Q2: What is the procedure of the lesson study process in your school? If the lesson study process was selected to promote integrated teaching and learning, what do you think should be done?

Q3: In your view, what factors contribute to the success of lesson study within the school?

3. Experts' opinions of the Online Professional Learning Community

Q1: What are the components and characteristics of each element of the online PLC?

Q2: What factors will make the Online PLC successful?

Q3: What kind of environment should be in the online PLC and should there be any computer supported collaborative learning tools?

Based on the sample questions above, the researcher conducted a semi-structured interview with 17 teachers in science, mathematics and technology. In addition, semi-structured interviews were conducted with 9 experts from STEM instructional design, CSCL and online professional learning communities, on the lesson study concept. In this interview, the researcher followed these steps:

1. Develop the interview schedule and sampling method;
2. Conduct the interview and record data;
3. Analyze the interview data using the following techniques: a) Data reduction; b) Data display; c) Verification. Each interview at least 25 minutes (Galletta, 2012).

In addition, computer program was used to improve the efficiency of data management and analysis by coding the interviews (Mouter & Vonk Noordegraaf, 2012).

Results

The data from this study is divided into two parts: 1. Data from the study on the state of STEM teaching and learning and the PLC of elementary school teachers in private educational institutions. 2. Data from expert opinion studied to understand the state of STEM instruction, the components of lesson study, and information technology systems in support of collaborative learning. The details of the data analysis are as follows:

Part 1: Data from the study on the state of STEM instructional learning and the PLC of elementary school teachers in private educational institutions.

Understanding of STEM teaching and learning

Table 1

The number of times informants mentioned (f) of understanding of STEM instructional design in private primary schools. (n=17)

Category	Type / Description	Number of times mentioned (f)
Understanding about STEM instructional design	Guidelines for Integrating Science, Technology and Mathematics	3
	Organizing activities using the engineering design process.	4
	Focus on problematic situations.	1
	Issues related to daily life.	2
	Conducting learning activities that focus on learners' hands-on activities and finding them with open-ended questions.	5
	Assessment of learners in all aspects of teaching management.	4

As shown in table 1, the study found that some instructors had misconceptions, such as encouraging students to create a piece of work, but not completing assignments or a way to use it to solve a problem that examines the learner's understanding through action was not achieved. In addition, the teaching and learning approach could not be applied in the classroom because most teachers were of the opinion that there was already a heavy teaching workload, so if the STEM instruction was added, teachers would not be able to follow the schedule. Misconceptions about STEM in terms of job creation included misunderstanding that doing work related to content, such as paper making, meant that such activities were STEM activities or in other instances, designing learning activities that lack clearly defined situations, problems, and challenges.

For example, one teacher's answer, "Let the students do the work, but the creation of this piece does not set the problem situation. The students search the Internet for information".

Moreover, from interviews with teachers on issues related to learning management, it was clear that teachers misunderstood that they needed to teach all subjects alone, so they believed that their burden was increased. Teachers believe that they need to take responsibility for all 4 subjects in the hours they teach.

In addition, some teachers did not understand the term “engineering design process”, abbreviated as “E (of STEM)”, they did not know what steps are to be taken, and how to proceed. For example, one teacher's answer, “I have never heard of engineering design processes”.

Understanding of lesson study

Table 2

The number of times informants mentioned (f) of understanding of lesson study and PLC in private primary schools. (n=17)

Category	Type / Description	Number of times mentioned (f)
Understanding lesson study and professional learning community	Plan for implementation of lesson study.	5
	Teach and observe teaching from fellow teachers.	2
	Reflect on the results of observed teaching.	3
	Professional learning community	1

As seen in table 2, the study found that most teachers did not know about lesson study while some informants understood that it was relevant to the learning of local communities. It is clear that teachers do not understand the concept of lesson study. In terms of meaning, lesson study process, understanding of the goals of teaching observation in the classroom that emphasize student learning, as well as the reflection stage of what is observed from the classroom.

For example, one teacher's answer, “The school administrators or academic advisor used to observe my teaching by holding a form to evaluate my teaching style”. In the context of the school, lesson study is conducted in the form of supervised teaching by specialists and meetings of individual groups. The content of the conference is mostly related to teachers’ work, but only a small portion deals with issues relating to student learning. For example, one teacher's answer, “There is a class chief meeting held from each subject group to present various actions such as organizing a science camp, etc., which conduct a meeting once a month”.

Understanding of technology to support cooperative learning in the form of an online professional learning community

Table 3

The number of times informants mentioned (f) about information technology to support collaborative learning in private schools. (n=17)

Category	Type / Description	Number of times mentioned (f)
Use of Information Technology to support collaborative learning in private education Institutions.	Communication area	9
	Content sharing area	3
	Community area	2
	Supportive and personal tools	0

As seen in table 3, the study found that teachers have a responsibility to teach and work with documents related to students and other activities such as student history registration, general affairs in the school, resulting in the use of information technology to help communicate. Most interview informants use a chat program installed on their mobile phone for communication. For example, one teacher's answer, "There are chat programs such as LINE for setting up groups of each subject to inform news". Sometimes it is used as a way to share content among teachers and information as well. As most of the information exchanged this way is in one-on-one conversations, this form of communication occurs in an informal manner. In addition, informants have not mentioned the application of various online systems, such as knowledge management systems, learning management systems, which these online systems will have IT tools that support personal use to manage settings related to the exchange of knowledge between members.

Part 2: Data from expert opinion studies including STEM instructional learning, computer supported collaborative learning, online learning communities, and the concept of lesson study as follows:

1. STEM instructional learning in Thailand has been known for approximately 3 years. Many agencies have developed guidelines for understanding STEM in several ways, such as training and disseminating documents through various channels. However, such efforts are not covered in every region and every institution, resulting in different perceptions and understanding of STEM in each school, for example, teaching science, technology, or mathematics as the core of the operation, opening a STEM course, and organizing STEM camps. Whatever form of learning takes place, with STEM there is a core intention to integrate science, technology and math in order to encourage students to learn and connect their knowledge to everyday life. This includes encouraging learners to study problem situations, so they can practice problem solving.

For example, one expert's answer, "Most teachers understand the concept of integration, but STEM is what promotes thinking and problem solving. Engineering makes STEM more than traditional integration". The application of knowledge, science, mathematics and technology through the implementation of the process of problem solving is varied, for instance, using an engineering design process involves identifying problems, gathering information, creating ideas, and choosing the best ideas, planning action, testing and revising the solution, and offering new solutions. However, the ability to integrate knowledge is sometimes lacking in some areas, for example, when the teacher needs to consider continuity of content. In the effort to link content to everyday life, students' actions to solve problems may be insufficient, or methods used to tackle a problem may not be diverse enough.

When instructors use the STEM instructional design, they need to define the details of the problem situation and the challenge to the learner. Then the student conducts activities in accordance with the engineering design process or problem solving process or learning management using the investigative process together with the problematic topic of the activity. For example, one expert's answer, "From the perspective of elementary education, STEM instructional design will be a learning environment based on integrated learning management with a theme or topic defined by the scientific process of inquiry learning". The use of appropriate teaching techniques and context can lead students to acquire improved mental and problem solving skills in order to link content to everyday life. In addition, the measurement and evaluation should be conducted in accordance with stated learning objectives. The educational process should incorporate multimedia, or the use of appropriate materials to help students learn and understand content.

2. The concept of lesson study is a guideline for the development of teaching and professional development of teachers originating in Japan. This concept involves a grouping of teachers to develop teaching techniques that focus on developing learners systematically and continuously within the context of the real class. Participating teachers have mutual trust, which leads to sharing of knowledge and learning. Teachers can be active in lesson study within their school, between schools or even across larger zones. But in any form, there are similar steps that a group member must perform, such as setting a goal, planning for joint lesson development, teaching and observation, and concluding teaching reflection. For example, one expert's answer, "The process begins with a group to explain the process of the lesson study has three steps: 1. Plan: it is planned before writing a learning management plan to consider content and analysis of learning indicators by thinking together among fellow teachers by using time intervals or e-mail conversations, once the feedback is received, the learning plan will be adjusted. 2. Do: it is teaching and teaching observation, however observing classes may not be done more often, teaching schedules may not be attended. 3. See: it is a reflection of the results of teaching observation. There will be a scheduled time to reflect. It is performed when members are all available".

However, in order to make the lesson study successful, it is important to have an understanding of the procedures of lesson study for the members to join. From the beginning of lesson study, a trust strategy should be developed between the members of the group. This will improve the motivation of members within the group to adjust their thinking and work method which in turn affects instructional design and development of learner-centered lessons.

3. Information technology to support collaborative learning today has a variety of capabilities to encourage people to come to the community; online professional learning allows people to communicate and exchange learning experiences. Therefore, in selecting information technology to support shared learning, the patterns of activities and the characteristics of the members must be considered to determine if they concern basic knowledge of the use of information technology, and the nature of the equipment that members are familiar with and use regularly. In addition, the use of information technology to support collaborative learning should follow clear procedures with clear objectives and tools. For example, one expert's answer, "In the online PLC system, there should be a clear event calendar for all members to know each other's action plans, as well as being able to perform the duties that they have planned together". Then, teachers must be educated in the use of the tools to build a knowledge base and confidence in using them. After that, activities should be organized for ongoing interaction including consideration of elements other than having members share the tools that will be used to exchange learning. The online learning community development also needs to consider other features: the process of creating and transferring knowledge, having a common motive, and sharing responsibility for learners' achievement. Also, it is important to consider the online PLC environment, so that the development of community-based online learning model is sustainable.

Discussion and Conclusion

Based on the analysis of results of the study of STEM instructional and PLCs in elementary private schools as well as the results of opinions from experts regarding the conditions of STEM teaching and learning, the elements of lesson study, and information technology tools to support collaborative learning, the researcher would like to divide the discussion of the results as follows:

Teachers' View of STEM Instructional Design

In the group of teachers who were interviewed on this research, it was found that they have misunderstandings as a result of their lack of continuous professional development about STEM education. Despite some having had face-to-face training of a few days or even self-study on the website, this appears to be insufficient for teachers to understand and be able to design STEM units. To prepare for professional development in STEM education, a continuous professional development plan that should consist of a variety of approaches must be designed (EdSurge, 2014; Islam, 2016). It must be organized to educate and focus on practical exercises related to the STEM teaching and learning method through grouping in a teachers' PLC, which is one method to achieve continuous professional development. This collaboration allows teachers to share perspectives or opinion about teaching and learning that result to all members in the group get knowledge and apply for design STEM learning units. Teachers who participate will have understanding and confidence in the use of STEM teaching method in the classroom. In addition, the important point of understanding the model of STEM learning management, as derived from the study of expert opinions, can be implemented in many forms, such as teaching and learning management integrating science, mathematics, and technology into the engineering process as a guideline for action, and learning management via the procedures of inquiry with a specific topic or issue. Therefore, professional development facilitators should consider these forms of STEM learning to be synthesized and provided as a means to transfer knowledge and practice to teachers in a variety of ways to enhance awareness and understand the importance of learning management in accordance with the STEM education approach as one way to help develop students to have the 21st century skills (Wahono & Chang, 2019).

Teachers' Views on Lesson Study

This concept concerns teachers' continuous professional development based on the Japanese practice (C.C. Lewis, 2012). Its purpose is to develop teachers' ability to manage their teaching practice in the context of their own school. However, this lesson study concept has already been implemented by several groups of teachers in certain schools. As shown by the results of the interviews, the teachers' comments show they did not understand lesson study and that they could not explain the process of a lesson study. So, there should be an understanding of the definition, elements, and process of the lesson study process prior to the instructor joining the group, as well as studying the context of the school and creating understanding of the personnel in the school from the school administrator level, the teaching staff and various support departments before starting the lesson study process. Building mutual understanding may be carried out by formulating policies from school administrators that will facilitate the creation of a school environment as a place to exchange knowledge among members (National Educational Welfare Board, 2008) such as set strategies for driving lesson study approach etc.

In addition, the lesson study plan of action should be clearly defined and should be a mutual agreement among members within the group. Then they can proceed to the lesson study procedure, including group goal setting, lesson plan development, teaching and observation, and teaching reflection. In addition, the lesson study grouping for the STEM instructional design will focus on providing students with problem-solving skills that will be able to link knowledge from various disciplines to solve real-life problems (Coenders & Verhoef, 2019). Considering the integration of teacher members of the STEM instructional design, it is recommended that volunteer teachers be included in the teaching of science, mathematics and technology and help develop STEM lessons. The teacher would be the volunteers that are the

result of internal motivation, such as the need to help others and external motivation, such as seeing the benefits of students learning (Finkelstien, 2009). The integration of teacher members will be one way to help the teachers see the link between the content of each level. This will result in the student learning and able to connect the knowledge gained to use in real life. In order for the lesson study to be sustainable, a strategy to motivate and convince the members of the lesson study group should be provided.

Teachers' Views of using Information Technology to Support Collaborative Learning in the Form of an Online PLC

The development of an online PLC requires that factors be considered in terms of the choice of CSCL in order to build relationships among members within the community and a collaborative team culture within the context of the school. In addition, consideration should be given to various factors, and the context of the school should be studied prior to implementing the online PLC; issues to address include the role of members in online PLC that will show different behaviors in each activity type such as post, reply, share (Angeletou, Rowe, & Alani, 2011), the ability to use the technology, presentation of the teaching schedule in the learning community, and posting online learning activities on the PLC to build trust among the members of the learning community. These examples are to be used to design and organize the online learning community, as well as to guide the interactions of group members. The use of computer tools to support collaborative learning in order to build relationships among members of the community and a collaborative team culture within the context of the school should also be considered. This includes encouraging members who are teachers in the science, mathematics and technology groups to join the online learning community and to incorporate Garrison's three elements (Garrison, 2007): social presence, cognitive presence and teaching presence, whose role in the PLC is regarded as important for communication or exchange of knowledge between members. Practitioners must identify and build knowledge through integration and reflection in the online PLC, by forming discussions in the community regarding learning of the online profession that will encourage the participation and educational achievement of members. In addition, consideration of factors that represent the success of the online PLC, such as access to membership, the learning activities organized by the members, and understanding how members participate in the online learning community will be clearer by specifying what participants need to do, how many of the participants will be able to participate, and individual's ability to use technology.

Recommendations for Practice and Future Research

Thus, the development of an online PLC in schools to promote STEM instructional design should take into consideration three points: 1. Individual members who participate in the online PLC should include science teachers, math teachers, and technology teachers, support staff or facilitators, including school administrators, and technical staff. 2. Information technology means a system or instrument that will be used as a medium to support collaborative learning exchange between members and 3. Content means the structuring of the content that will appear in the online learning community and the scheduling of the members' activities. As for the determination of various activities in Online PLC, it is necessary to consider the context and environment under the acceptance of the control of the behavior of members in the community because the determination of activities that are conducive to the openness of members will be a way to reduce The effects that may arise from expressing opinions between members of the community, including exchanging, learning and showing different attitudes

between each other. The design of activities with good control or management will result in the participation of members in the form of friends helping friends for the instructional design. This will enhance the professional development persistently and sustainably.

References

- Angeletou, S., Rowe, M., & Alani, H. (2011). *Modelling and analysis of user behaviour in online communities*. In L. Aroyo, C. Welty, H. Alani, J. Taylor, A. Bernstein, L. Kagal, N. Noy, & E. Blomqvist (Eds.). Paper presented at 10th International Semantic Web Conference Bonn, Germany, October 23-27 (pp.35-50). Heidelberg: Springer. doi: 10.1007/978-3-642-25073-6_3
- Aregamalage, S. V. P., Hong, S., & Fang, H. (2017). STEM Teacher Education and Professional Development and Training: Challenges and Trends. *American Journal of Applied Psychology*, 6(5), 93-97. doi:10.11648/j.ajap.20170605.12
- Battersby, S. L., & Verdi, B. (2015). The culture of professional learning communities and connections to improve teacher efficacy and support student learning. *Arts Education Policy Review*, 116(1), 22-29. doi:10.1080/10632913.2015.970096
- Caena, F. (2011). Education and training 2020 thematic working group 'professional development of teachers': Literature review quality in teachers' continuing professional development. Retrieved from http://ec.europa.eu/dgs/education_culture/repository/education/policy/strategic-framework/doc/teacher-development_en.pdf
- Cheng, P. L. (2017). *Professional Learning Community (PLC): Technology integration at a title I elementary school* (Doctoral dissertation). Education Department, San Jose State University. doi: 10.31979/etd.58wj-dk5q
- Coenders, F., & Verhoef, N. (2019). Lesson study: Professional Development (PD) for beginning and experienced teachers. *Professional Development in Education*, 45(2), 217-230. doi: 10.1080/19415257.2018.1430050
- Damjanovic, V., & Blank, J. (2018). Building a professional learning community: Teachers' documentation of and reflections on preschoolers' work. *Early Childhood Education Journal*, 46(5), 567-575. doi: 10.1007/s10643-017-0888-0
- Dehdary, N. (2017). A look into a professional learning community. *Journal of Language Teaching & Research*, 8(4), 645-654. doi: 10.17507/jltr.0804.02
- Dixon, F. A., Yssel, N., McConnell, J. M., & Hardin, T. (2014). differentiated instruction, professional development, and teacher efficacy. *Journal for the Education of the Gifted*, 37(2), 111-127. doi: 10.1177/0162353214529042
- Draper, D. P. (2014). *Guiding the work of professional learning communities: Perspectives for school leaders* (Doctoral dissertation). Portland State University.
- Easton, L. B. (2012). Principles of design energize learning communities: Practical tips put the emphasis on "Learning". *Journal of Staff Development*, 33(4), 49-54.
- EdSurge. (2014). *How teachers are learning: professional development remix*. Retrieved from <https://d3e7x39d4i7wbe.cloudfront.net/uploads/pdf/file/3/PD-Remix-EdSurge-Report-2014.pdf>
- Feffer, J. F. (2015). *Teacher learning within professional learning communities* (Doctoral dissertation). California State University.

- Finkelstien, M. A. (2009). Intrinsic vs. extrinsic motivational orientations and the volunteer process. *Personality and Individual Differences*, 46(5), 653-658.
doi: 10.1016/j.paid.2009.01.010
- Galletta, A. (2012). *Mastering the Semi-Structured Interview and Beyond : From Research Design to Analysis and Publication*. NY: NYU Press.
- Garrison, D. R. (2007). Online community of inquiry review: Social, cognitive, and teaching presence issues. *Journal of Asynchronous Learning Networks*, 11(1), 61-72.
doi:10.24059/olj.v11i1.1737
- Hird, M., Larson, R., Okubo, Y., & Uchino, K. (2014). Lesson study and lesson sharing: An appealing marriage. *Creative Education*, 5(10), 769-779. doi:10.4236/ce.2014.510090
- Islam, M. T. (2016). Teacher development approaches and strategies in BRAC nobodhara school. *International Journal of Learning & Development*, 6(1), 25-41.
doi:10.5296/ijld.v6i1.8846
- Jamjuree, D. (2017). Teacher training and development in Thailand. *Journal of Research and Curriculum Development*, 7(2), 7-19.
- Järvelä, S., Kirschner, P. A., Panadero, E., Malmberg, J., Phielix, C., Jaspers, J., . . . Järvenoja, H. (2015). Enhancing socially shared regulation in collaborative learning groups: designing for CSCL regulation tools. *Educational Technology Research and Development*, 63(1), 125-142. doi:10.1007/s11423-014-9358-1
- Jennifer, M. T. (2016). *Examining teachers' experiences in a professional learning community focused on integrating technology into literacy instruction* (Doctoral dissertation), Iowa State University. Retrieved from <https://lib.dr.iastate.edu/etd/15224>
- Jeong, H., & Hmelo-Silver, C. E. (2016). Seven affordances of computer-supported collaborative learning: How to support collaborative learning? How can technologies help? *Educational Psychologist*, 51(2), 247-265.
doi: 10.1080/00461520.2016.1158654
- Kenan Foundation Asia. (2019). *Think transforming thai education is impossible? Think again*. Retrieved from <https://www.kenan-asia.org/transforming-thai-education/>
- Kham-o-part, P. (2018). The model of teachers' professional learning community for the non-formal and informal educational center in Thailand's upper northern region. *Humanities, Arts and Social Sciences Studies*, 18(2), 444-462.
- Kyndt, E., Gijbels, D., Grosemans, I., & Donche, V. (2016). Teachers' everyday professional development: Mapping informal learning activities, antecedents, and learning outcomes. *Review of Educational Research*, 86(4), 1111-1150.
doi:10.3102/0034654315627864
- Lewis, C. (2015). What is improvement science? Do we need it in education? *Educational Researcher*, 44(1), 54-61. doi:10.3102/0013189x15570388
- Lewis, C. C. (2012). *How do Japanese teachers improve their instruction? Synergies of lesson study at the school, district and national levels*, Vol. 2016 (p. 21). Retrieved from http://sites.nationalacademies.org/dbasse/cs/groups/dbassesite/documents/webpage/dbasse_084385.pdf
- Lewis, C. C., Perry, R. R., Friedkin, S., & Roth, J. R. (2012). Improving teaching does improve teachers: Evidence from lesson study. *Journal of Teacher Education*, 63(5), 368-375.
- Mouter, N., & Vonk Noordegraaf, D. (2012). *Intercoder reliability for qualitative research: You win some, but do you lose some as well?* Paper presented at the Proceedings of the 12th TRAIL Congress, 30-31 October 2012, Rotterdam, Netherlands.

- National Commission on Teaching & America's Future. (2010). *STEM teacher in professional learning communities: A knowledge synthesis*. Retrieved from https://www.wested.org/online_pubs/resource1097.pdf
- National Educational Welfare Board. (2008). *Developing a code of behaviour: Guidelines for schools*. Retrieved from https://www.tusla.ie/uploads/content/guidelines_school_codes_eng.pdf
- Office of Basic Education Commission (OBEC), Faculty of economics Thammasat University, & UNICEF Thailand. (2014). *Public Expenditure Tracking Survey (PETS) on the 15-year free education program: Kingdom of Thailand*. Retrieved from <https://www.unicef.org/thailand/reports/public-expenditure-tracking-survey-pets-15-year-free-education-program-kingdom-thailand>
- Oh Song, K., & Choi, J. (2017). Structural analysis of factors that influence professional learning communities in Korean elementary schools. *International Electronic Journal of Elementary Education*, 10(1), 1-9. doi: 10.26822/iejee.2017131882
- Owen, S. (2014). Teacher professional learning communities: Going beyond contrived collegiality toward challenging debate and collegial learning and professional growth. *Australian Journal of Adult Learning*, 54(2), 54-77.
- Park, N., & Yang, A. (2012). Online environmental community members' intention to participate in environmental activities: An application of the theory of planned behavior in the Chinese context. *Computers in Human Behavior*, 28(4), 1298-1306. doi: 10.1016/j.chb.2012.02.013
- Patton, K., Parker, M., & Tannehill, D. (2015). Helping teachers help themselves: Professional development that makes a difference. *NASSP Bulletin*, 99(1), 26-42. doi:10.1177/0192636515576040
- Poovey, R. R. (2017). Elementary teacher reflection in professional learning communities and teacher learning. In D. A. Rucinski (Ed.), *Real world professional learning communities: Their use and effects* (pp. 39-54). London: Rowman & Littlefield.
- Popp, J. S., & Goldman, S. R. (2016). Knowledge building in teacher professional learning communities: Focus of meeting matters. *Teaching and Teacher Education*, 59, 347-359. doi: 10.1016/j.tate.2016.06.007
- Rinke, C. R., Gladstone-Brown, W., Kinlaw, C. R., & Cappiello, J. (2016). Characterizing STEM teacher education: Affordances and constraints of explicit STEM preparation for elementary teachers. *School Science and Mathematics*, 116(6), 300-309. doi:10.1111/ssm.12185
- Shabani, K. (2016). Applications of Vygotsky's sociocultural approach for teachers' professional development. *Cogent Education*, 3(1), 1252177.
- Shernoff, D. J., Sinha, S., Bressler, D. M., & Ginsburg, L. (2017). Assessing teacher education and professional development needs for the implementation of integrated approaches to STEM education. *International Journal of STEM Education*, 4(1), 13.
- Shúilleabháin, A. N. (2015). Lesson study as a form of in-school professional development: Case studies in two post-primary schools. Retrieved from https://www.researchgate.net/profile/Aoibhinn_Ni_Shuilleabhain/publication/275262988_Lesson_Study_as_a_form_of_in-School_Professional_Development/links/55362d890cf218056e92d779/Lesson-Study-as-a-form-of-in-School-Professional-Development.pdf
- Slavit, D., Nelson, T. H., & Lesseig, K. (2016). The teachers' role in developing, opening, and nurturing an inclusive STEM-focused school. *International Journal of STEM Education*. Retrieved from <https://stemeducationjournal.springeropen.com/articles/10.1186/s40594-016-0040-5>

- Sompong, S., Erawan, P., & Dharm-tad-sa-na-non, S. (2015). The development of professional learning community in primary schools. *Academic Journals: Educational Research and Reviews*, 10(21), 2789-2796. doi: 10.5897/ERR2015.2343
- Srikoom, W., Hanuscin, D. L., & Faikhamta, C. (2017). Perceptions of in-service teachers toward teaching STEM in Thailand. *Asia-Pacific Forum on Science Learning and Teaching*, 18(2). Retrieved from https://www.eduhk.hk/apfslt/v18_issue2/srikoom/index.htm
- Tam, A. C. F. (2015). The role of a professional learning community in teacher change: A perspective from beliefs and practices. *Teachers and Teaching*, 21(1), 22-43.
- Tantranont, N. (2009). *Continuing professional development for teachers in Thailand*. (Doctoral dissertation). University of Warwick, England. Retrieved from <http://go.warwick.ac.uk/wrap/2242>
- Thompson, D. (2015). *An analysis of the perceived impact of lesson study on improving secondary school STEM teacher effectiveness* (Doctoral dissertation). University of Central Florida, Orlando, Florida. Retrieved from <http://stars.library.ucf.edu/etd/1311/>
- Trust, T., & Horrocks, B. (2017). "I never feel alone in my classroom": Teacher professional growth within a blended community of practice. *Professional Development in Education*, 43(4), 645-665. doi: 10.1080/19415257.2016.1233507
- Tsiotakis, P., & Jimoyiannis, A. (2016). Critical factors towards analysing teachers' presence in on-line learning communities. *The Internet and Higher Education*, 28(January, 2016), 45-58. doi: 10.1016/j.iheduc.2015.09.002
- Turner, C. J. (2015). *Impact of professional learning community design on teacher instruction* (Doctoral dissertation), University of Arkansas, USA.
- Vu, P., Cao, V., Vu, L., & Cepero, J. (2014). Factors driving learner success in online professional development. *International Review of Research in Open and Distance Learning*, 15(3), 20. doi: 10.19173/irrodl.v15i3.1714
- Wahono, B., & Chang, C.-Y. (2019). Assessing teacher's Attitude, Knowledge, and Application (AKA) on STEM: An effort to foster the sustainable development of STEM education. *Sustainability*, 11(4), 950. doi: 10.3390/su11040950
- Watson, C. (2014). Effective professional learning communities? The possibilities for teachers as agents of change in schools. *British Educational Research Journal*, 40(1), 18-29. doi: 10.1002/berj.3025