Investigating the Use of Lesson Study with Preservice Science Teachers

Fulden GÜLER NALBANTOĞLU
Ege University
fulden.guler@ege.edu.tr

Jale ÇAKIROĞLU
Middle East Technical University
jaleus@metu.edu.tr

Özgül YILMAZ TÜZÜN
Middle East Technical University
ozgul@metu.edu.tr

Abstract

The study aimed to explore the integration of lesson study into science teacher education programs to enhance preservice science teachers' pedagogical content knowledge (PCK) for STEM. The lesson study cycle encompassed planning, teaching, reflecting, re-teaching, and re-reflecting phases, and the participants' experiences regarding PCK for STEM in these phases were investigated. Lesson study was incorporated into the Practice in a Science Teaching course within the science teacher education program, and four lesson study cycles were completed. Participants designed four research lessons in the format of content representation focusing on different science units and implemented them in middle school classrooms. A case study was employed, and the four preservice science teachers in their final year participated in the study. In-depth data were collected through various sources, including interviews, content representation, and observation protocols, and descriptive analysis was used to analyze the data. The main findings of the study revealed that the phases of lesson study were influential in improving preservice science teachers' PCK for STEM. The collaborative nature of lesson study allowed preservice science teachers to construct knowledge collectively, teach in real classroom environments, observe their peers, and reflect on the lessons. These activities enhanced their understanding of the curriculum, learners, instructional strategies, and assessment in the context of STEM education at the end of the study.

[This paper was published in: "EJER Congress 2023 International Eurasian Educational Research Congress Conference Proceedings," Ani Publishing, 2023, pp. 148-162]

Keywords: *Lesson study, pedagogical content knowledge, preservice science teachers, teacher education*

Introduction

Lesson study is "a systematic investigation of classroom pedagogy conducted collectively by a group of teachers rather than by individuals, with the aim of improving the quality of teaching and learning" (Tsui & Law, 2007, p. 1294). Lesson study has the potential to offer effective learning methods when integrated into teacher education programs (Bjuland & Mosvold, 2015; Leavy & Hourigan, 2016; Sims & Walsh, 2009). A review of the relevant literature reveals that lesson study is integrated in various ways into teacher education programs. One research line merges the characteristics of microteaching and lesson study, termed 'microteaching lesson study' (Fernandez, 2010). The main distinction between lesson study and microteaching lesson study lies in the fact that microteaching lesson study requires implementing a research lesson with a small group of peers rather than middle or high school students in an actual classroom environment (Bahcivan, 2017; Carrier, 2011; Karlström & Hamza, 2019; Matthew, 2018). Another line of research integrates lesson study into methods courses or field experience courses within teacher education programs and implements research lessons in a real classroom setting (Belge-Can, 2019; Juhler, 2016; Marble, 2007). The current study aligns with this line of integration.

Lesson study is cyclical and consists of three core phases: planning, teaching, and reflecting. Re-teaching and re-reflecting are carried out optionally. All five phases were followed in the current study. In the planning phase, a group of teachers (four to six individuals) come together to determine the learning objectives of the lesson and prepare the research lesson. When determining these objectives, they may focus on challenging topics for students or objectives related to a new approach used in the curriculum. In this study, objectives related to the STEM education were established. In the teaching phase, the research lesson is implemented in the classroom by one teacher in the group, while other teachers try to observe this lesson as much as possible and collect data. In the reflecting phase, the lesson study group makes improvements to the research lesson based on their data and observations to enhance students' learning. These improvements could include rewriting the objectives or changing teaching or assessment methods. The next step, re-teaching, involves implementing the revised research lesson by another teacher in the group in another classroom in the same grade. After the implementation, further improvements are made to the lesson plan in the re-reflecting phase (Dudley, 2015).

It is believed that lesson study can provide an appropriate context to bridge theory and practice for preservice teachers (Dudley, 2015) and enhance their pedagogical content knowledge (PCK) (Juhler, 2016). PCK is defined as "the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction" (Shulman, 1987, p. 8). Among different alternatives, we utilized Magnusson et al.'s (1999) PCK model and tailored it as "PCK for STEM" in the present study. Four components of PCK were employed as follows: (1) knowledge of curriculum, (2) knowledge of learners, (3) knowledge of instructional strategies, and (4) knowledge of assessment.

Although lesson study is frequently conducted with in-service teachers (Lee & Tan, 2020; Verhoef et al., 2015), studies involving preservice teachers have been on the rise (Boz & Belge-Can, 2020; Ni Shuilleabhain, & Bjelland, 2019). One of the significant contributions of this study is the integration of lesson study into science teacher education programs, providing meaningful experiences for preservice science teachers to develop PCK for STEM. In this study, sources for strengthening PCK, such as collaborative lesson planning, teaching in the classroom, observing teaching, and reflecting on teaching, were applied through lesson study (Akerson et al., 2017; Barendsen & Henze, 2019). In this context, the study focused on the role of the different phases of lesson study in the PCK development of preservice science teachers. The research question addressed in this study is: 'Which phases of lesson study have contributed to the development of preservice science teachers' PCK for STEM?'"

Method

Research Design

The case study, one of the qualitative research methods, was utilized in this study (Creswell, 2013). In-depth data were collected from multiple sources through four lesson study cycles. Participants' experiences regarding PCK for STEM during the planning, teaching, reflecting, re-teaching, and re-reflecting phases of lesson study cycles were investigated.

Research Sample

Purposive sampling was utilized (Patton, 2002), and specific criteria were established for participant selection as follows: (1) being senior preservice science teachers, (2) having completed many of the content courses (Physics, Earth Sciences), pedagogical courses (Classroom Management, Psychology of Education) and pedagogical content knowledge courses (Methods of Science Teaching, Laboratory Applications in Science), (3) volunteering to participate in the group work. Consequently, four preservice science teachers enrolled in the Practice in Science Teaching-1 course participated in the current study. Pseudonyms were used, and consent forms were obtained from the participants. Three participants were female (Ada, Ecce, Defne), and one was male (Deniz). Participants had similar GPAs and had not previously taken engineering-related courses during their undergraduate education.

Research Instrument and Procedure

The lesson study was integrated into the Practice in Science Teaching-1 course in the science teacher education program in Turkey. Preservice teachers were required to attend a two-hour theoretical course at the university and gain six hours of teaching experience weekly as part of this course. The research lessons were implemented in a 6th-grade classroom in this study.

Initially, during the planning phase of the lesson study, participants followed the yearly science curriculum and selected objectives from four different units for this study. In the planning meetings, they agreed on the objectives, determined the teaching and assessment methods, and considered learners' misconceptions and difficulties while designing the research lesson. Participants met four to six times during the planning phases of the lesson study. Subsequently, one participant from the group implemented the research lesson in a real classroom environment, while three participants observed the lesson and collected data. For the first lesson study cycle, it took three lesson hours to apply the research lesson, whereas it took four lesson hours in the other lesson study cycles. Next, the group convened after the teaching phase and reflected on their experiences and observations related to the research lesson. Some revisions were made to the research lesson, such as modifying the objective or changing the assessment method. Afterward, another preservice science teacher from the group re-taught the revised research lesson to another classroom at the

same grade level. The observer preservice science teachers monitored the lesson and collected the data. Finally, during the re-reflecting phase, the group made further revisions to the research lesson based on the observations and data. Consequently, four lesson study cycles were completed at the end of the study, and it took approximately one month to complete one cycle. Each preservice science teacher implemented the first version of the research lesson and a revised version of the research lesson. One of the researchers was involved in the planning and reflecting meetings, guided the group discussions, and observed the research lessons without interrupting the lesson.

Data were collected through semi-structured interview questions, content representation (CoRe), and observation protocols. Firstly, pre-interview questions were administered after the planning phase, and post-interview questions were conducted after the teaching phase of the lesson study. Post-interview questions were revised by considering the data from the observation protocol. Each participant was interviewed eight times throughout the study, and it took nearly one hour to complete each interview. Secondly, content representation (CoRe) was utilized for lesson planning tool in the present study (Aydin et al., 2013). It comprises two axes: the main concepts to be taught are placed on the horizontal axis, and prompts regarding instructional decisions (such as learners' difficulties, methods, assessment, etc.) are placed on the vertical axis. Participants designed collaborative CoRes to prepare research lessons in the planning meetings and revised them in the reflection meetings. Thirdly, an observation protocol was prepared based on the revised version of the PCK for STEM framework. It was used during the teaching phase of the lesson study, and observer preservice science teachers completed the protocols in the teaching and re-teaching phases. Thirty hours of STEM lessons were observed in the context of this study.

Data Analysis

The data were analyzed descriptively. Firstly, the phases of the lesson study were listed as follows: planning, teaching/re-teaching, observation of teaching, and reflecting/re-reflecting. Then, participants' views about which phases of lesson study were effective in promoting their PCK for STEM were determined. For instance, one preservice science teacher mentioned that teaching was influential in terms of identifying students' engineering-related misconceptions during the post-

interviews. We also cross-referenced and compared the post-CoRe to determine if this had been integrated as a learners' difficulty.

Finally, how many participants had specified particular phases of the lesson study related to each PCK for STEM component was ascertained. For example, we tallied the number of participants who emphasized how the observation of teaching helped them better comprehend the learners' understanding and recorded it in the table. We also utilized example statements to provide a deeper understanding of how participants' PCK for STEM was evolving in line with the phases of the lesson study.

Results

Table 1 provides an overview of how phases of lesson study periods influenced preservice science teachers' PCK for STEM. The findings related to each phase of the lesson study are presented below.

Table 1.

Phases of Lesson Study Contributing to Preservice Science Teachers' PCK for STEM

PCK Components/ Elements of Lesson Study	**Planning**	**Teaching**	**Observing the Lesson**	**Reflecting**
Curriculum	Ada Defne Ece Deniz	Ada Defne	-	Defne Ece
Learners	Ada Defne Ece Deniz	Ada Defne Ece Deniz	Ada Defne Ece Deniz	Ada Defne Ece Deniz
Instructional Strategies	Ada Defne Ece Deniz	Ada Defne Ece Deniz	Ada Defne Ece Deniz	Ada Defne Ece Deniz
Assessment	Ada Defne Ece Deniz	-	Ada Ece	Ada Defne Ece

Planning

All participants mentioned the positive impact of the planning phase of lesson study on all components of PCK for STEM. For example, Ada referred to her improved knowledge regarding knowledge of curriculum:

> We decided the objectives of the lesson as a group and defended our perspectives in the meeting. During the planning meetings, we criticized all ideas about different objectives and were open to criticism. For instance, I learned about mathematics objectives thanks to Defne. Her suggestion increased my awareness, and I started to examine the mathematics curriculum the way I examined the science curriculum (Ada, post-interview, 2).

As demonstrated above, Ada underscored the significance of planning meetings, particularly in establishing objectives related to mathematics and engineering (post-interview-2). Similarly, Ece highlighted how collaborative work during the planning phase positively affected her knowledge of learners as follows:

> The planning part was very effective for me regarding students' misconceptions. For instance, Deniz observed the 5th grade lessons as a cooperating teacher and faced misconceptions about the heat. Then, we argued about it in the planning meetings, and I realized that I had never thought about this misconception before (Ece, pre-interview, 3).

Furthermore, participants also mentioned that using the CoRe during planning meetings significantly contributed to enhancing their knowledge of the curriculum and learners. For example, Ece emphasized the benefits of preparing and adjusting the CoRe based on learners' misconceptions and difficulties:

> Thanks to CoRe, my knowledge was enhanced about which concepts students might have misconceptions about or at which points of the lesson might be challenging for them. If I detect misconceptions in any of the STEM fields, I start to think about which strategies I can use to understand whether they are eliminated or not. The two questions in the CoRe helped me a lot to develop an awareness of students' misconceptions and difficulties in the planning meetings. I know that teachers should be prepared before the lesson about these issues (Ece, pre-interview-4).

Consistent with Ece's statement, collaborative CoRe-3 and CoRe-4 were more comprehensive compared to CoRe-1 in terms of the difficulties students might encounter and potential misconceptions related to both science and other STEM disciplines.

Regarding knowledge of instructional strategies, all participants indicated that the planning meetings were instrumental in improving their understanding of various teaching strategies aligned with STEM education. Defne stated:

> If we had not prepared the plan as a group, I could not have learned about problem-based learning. Maybe I would never use it in STEM lessons. I might search the internet and examine the course books to learn about problem-based learning. However, I have learned in a better way by discussing it with my friends and you. There were many ideas about the strategy, and we had a chance to criticize the advantages and disadvantages. We discussed how to integrate different disciplines into problem-based learning, especially the engineering design process (Defne, pre-interview, 4).

Teaching

Many participants mentioned that the teaching phase of lesson study was influential in improving their knowledge of the curriculum, knowledge of learners, and knowledge of assessment. For instance, Deniz stressed that during the teaching phase, he started to realize students' understanding of a specific topic that he intended to teach. He said:

> We did not prepare our first STEM lesson plan according to the classroom environment. I mean, we did not think about the most basic questions that students could ask or what we would do if we faced misconceptions. However, as we teach and observe our friends' lessons, we now consider students' misconceptions and explanations about how we deal with them. The more we interact with the student, the more misconceptions we can detect (Deniz, pre-interview, 4).

As seen from the excerpt, Deniz mentioned that as he interacted with the students during the teaching phase, he started to identify misconceptions more easily. This was also reflected in the CoRes participants designed. The CoRes in lesson study 3 and lesson study 4 involved richer misconceptions and difficulties in science and other STEM disciplines. Moreover, collaborative

CoRes were also enriched with strategies on how to correct misconceptions (such as using concept cartoons, word association tests). Furthermore, participants began to note misconceptions and difficulties in science and STEM disciplines in their observation protocols filled out in lesson study 3 and lesson study 4.

Additionally, regarding knowledge of curriculum, Ada was able to connect different science topics during the teaching phase. For instance, she made connections between different science units (Solar eclipse and eye health) in the re-teaching phase of lesson study 1 (observation protocol-1). This point was not included in CoRe-1, but she stated that she could link different science topics more comfortably after teaching the lesson (post-interview-1) which referred her improved knowledge of curriculum.

Concerning knowledge of instructional strategies, all participants underlined that the teaching phase was one of the most important aspects of lesson study that contributed to their understanding of using design-centered teaching practices. For instance, Defne said:

> The teaching part made me notice the importance of completing the entire cycle of the engineering design process. I could not complete it in this lesson. If I had enough time, I could let students re-build their cars and underline speed concept more effectively. … I understand that using graphs was necessary for our lesson to visualize the concepts during my lesson and make a decision about the designs (Defne, post-interview, 2).

None of the participants valued the teaching phase regarding knowledge of assessment.

Observing the Lesson

Participants considered that their experiences during observing the lesson contributed to their knowledge of learners, knowledge of instructional strategies, and knowledge of assessment. For instance, Defne shared her experiences about observing her peers as follows:

> Experiencing what I learned during my undergraduate education in the classroom environment helped me to consolidate what I learned and noticed the deficiencies in my knowledge regarding teaching strategies. I also learned to integrate mathematics and engineering into teaching strategies. The observation form you gave us was also helpful. The

> implementation of the lesson plan had a positive effect on my development. Moreover, while my friends were observing my lesson, I felt lucky. Their feedbacks were really essential for my development (Defne, post-interview, 1).

As seen from the excerpt, Defne mentioned that observing the lesson helped her deepen her understanding of teaching strategies and provided an opportunity to improve her knowledge.

Similarly, Ece valued the significance of observing a peer in lesson study and explained how it contributed to her knowledge of assessment:

> While observing Ada's lesson, I realized that more emphasis should be done on how we plan to assess students' thermos designs. Ada tried to explain a little. However, I will discuss in the reflection meeting that the criteria list should be presented at the beginning of the engineering design process (post-interview, 3).

In a similar vein, Ada identified mathematics-related difficulties during the observation of teaching, which were not documented in the collaborative CoRe in planning meetings, and noted this point in her observation form. This demonstrated how the observation phase of the lesson study advanced her knowledge of learners.

Reflecting on the Lesson

Participants mentioned that the reflection phase of the lesson study was effective on all components of PCK for STEM development. For example, Defne, who had not previously used problem-based learning, felt much more confident during the re-teaching phase after the reflection phase, emphasizing that they made corrections by discussing the initial plan to address the problems that emerged during teaching (post-interview-4, CoRe-4). Similarly, Deniz noticed that the students had difficulty understanding the concept of energy transfer during the teaching phase of lesson study 3. In the following reflection meeting, Ece suggested a method to overcome this difficulty, and Deniz underlined that he would use this suggestion in his future classrooms (post-interview, 4). Additionally, Ada valued the importance of reflection about her advanced knowledge of assessment as follows:

> I think the last three questions in the observation form (proposing at least three points for revising CoRe) were practical. They are about what we could change in CoRe to make students better understand the lesson. For instance, some assessment methods did not work well in the classroom as we planned, such as the concept cartoon about speed in the second lesson plan. We changed the time of the implementation in the reflection meeting. Therefore, reflection meetings were helpful in criticizing the plan and making the necessary revisions in the assessment (Ada, pre-interview, 4).

Two participants mentioned that reflecting on the lesson contributed to their knowledge of curriculum. For instance, Defne said:

> In the first CoRe, we only wrote science objectives. We modified the science objective with my friends' suggestions. On the other hand, although we knew the importance of integrating engineering into the STEM lesson plan, we did not put it as a separate objective. I realized this discrepancy in the reflection meetings. I remembered the discussions between Ada and Ece while discussing revising the objectives. This discussion led me to examine mathematics and technology and design curriculum, and I suggested writing mathematics-related objectives in lesson study 2. (Defne, pre-interview, 4).

In summary, participants found the phases of the lesson study to be beneficial in developing their PCK for STEM. Participants had underdeveloped PCK at the beginning of the study; however, through their engagement in four lesson study cycles, they began to integrate STEM disciplines more effectively, and their PCK for STEM improved.

Discussion

Lesson study facilitates the creation of a collaborative learning environment and deepens preservice teachers' PCK (Belge-Can, 2019; Juhler, 2016). As evidenced by our findings, engaging in four lesson study cycles contributed to the development of preservice teachers' PCK. Below, we discussed how the various phases of lesson study influenced participants' PCK for STEM.

A fundamental aspect of lesson study is the collective construction of knowledge by the participants (Holden, 2022). Preservice science teachers mentioned that within the context of lesson study, they gained valuable insights from their peers' diverse perspectives in a collaborative work environment.

Participants emphasized that their teaching experiences during lesson study enhanced their understanding of the curriculum, knowledge of the learners, and knowledge of instructional strategies. These findings align with previous studies that underscore the impact of teaching experience on the development of preservice teachers' PCK (Aydin et al., 2013). Additionally, Bahcivan (2017) utilized micro-teaching lesson study and observed minor development in preservice teachers' knowledge of learners. The researcher concluded that this change was largely attributed to teaching peers. In our study, preservice science teachers implemented the research lessons in a real classroom environment as opposed to Bahcivan's (2017) study. Hence, it can be inferred that the teaching phase of the lesson study assisted participants in refining their knowledge of learners.

Furthermore, participants in the study frequently emphasized the significance of observing their peers during the teaching phase. Observation holds value as it allows for the "capture of teachers' knowledge-in-action" (Barendsen & Henze, 2019, p. 1144). Participants observed 30 hours of lessons throughout this study and completed observation protocols. Teaching experience and the observation of teaching both play influential roles in advancing PCK (Coenders & Verhoef, 2019; Grosman, 1990), as corroborated by our findings in this study.

Prior PCK studies have stressed that reflecting on teaching is a primary catalyst for PCK development (Carlson et al., 2019; Henze & Barendsen, 2019). Lee and Tan (2020) elucidated that through reflection, teachers engage in a "progressive building-upon of one another's observations and ideas to improve a lesson while discussing observations and sharing possible speculations underlying the observations" (p. 9). Most participants affirmed that reflection meetings were effective for all components of PCK for STEM, aligning with other studies advocating that reflection enhanced preservice teachers' PCK for STEM (Aydin-Gunbatar et al., 2020; Lertdechapat & Faikhamta, 2021).

Conclusion

This study integrated lesson study into the Practice in Science Teaching-1 course in the science teacher education program. Since one of the critical parts of lesson study is teaching, it is considered that incorporating lesson study is appropriate to implement it in the context of this

course, where opportunities are provided for preservice science teachers to teach in a real classroom setting. Additionally, developing PCK takes time and experience; therefore, multiple cycles for lesson study are preferred.

Recommendations

Future studies could consider the multidisciplinary nature of STEM education and engage preservice teachers from diverse departments, such as mathematics education, computer education, and instructional technology. A similar study involving teachers from different educational backgrounds could also be conducted. Finally, collecting and analyzing student data could further support the development of preservice teachers' PCK for STEM.

This study was derived from a part of the first author's doctoral dissertation.

References

Akerson, V. L., Pongsanon, K., Rogers, M. A. P., Carter, I., & Galindo, E. (2017). Exploring the use of lesson study to develop elementary preservice teachers' pedagogical content knowledge for teaching nature of science. *International Journal of Science and Mathematics Education*, *15*(2), 293-312.

Aydin, S., Demirdogen, B., Tarkin, A., Kutucu, S., Ekiz, B., Akin, F. N., ... & Uzuntiryaki, E. (2013). Providing a set of research-based practices to support preservice teachers' long-term professional development as learners of science teaching. *Science Education*, *97*(6), 903-935.

Aydin-Gunbatar, S., Ekiz-Kiran, B., & Oztay, E. S. (2020). Preservice chemistry teachers' pedagogical content knowledge for integrated STEM development with LESMeR model. *Chemistry Education Research and Practice*, *21*(4), 1063-1082.

Bahcivan, E. (2017). Implementing microteaching lesson study with a group of preservice science teachers: An encouraging attempt of action research. *International Online Journal of Educational Sciences*, *9*(3), 591-602.

Barendsen, E., & Henze, I. (2019). Relating teacher PCK and teacher practice using classroom observation. *Research in Science Education*, *49*(5), 1141-1175.

Belge-Can, H. (2019). Learning science teaching by taking advantages of lesson study: An effective form of professional development. *Journal of Educational Issues*, *5*(2), 150-169.

Bjuland, R. & Mosvold, R. (2015). Lesson Study in teacher education: Learning from a challenging case. *Teaching and Teacher Education, 52*, 83–90.

Carlson, J. Cooper, R. Daehler, K.R., Friedrichsen, P.J., Heller, J. Kirschner, S., Elliott, N.L., Marangio, K. & Wong, N. (2019). Vignettes illustrating practitioners' and researchers' application of the refined consensus of pedagogical content knowledge. In A. Hume, R. Cooper, & A. Borowski (Eds.), *Repositioning pedagogical content knowledge in teachers' knowledge for teaching science* (pp.93- 113). Springer.

Carrier, S. J. (2011). Implementing and integrating effective teaching strategies, including features of lesson study in an elementary science methods course. *The Teacher Educator, 46*(2), 145-160.

Coenders, F., & Verhoef, N. (2019). Lesson Study: professional development (PD) for beginning and experienced teachers. *Professional Development in Education, 45*(2), 217-230.

Creswell, J. W. (2013). *Qualitative inquiry and research design: Choosing among five traditions* (3rd ed.). Sage Publications.

Dudley, P. (2015). How lesson study works and why it creates excellent learning and teaching. In P. Dudley (Eds.), *Lesson study: Professional learning for our time* (pp. 1-28). Routledge.

Fernandez, M. L. (2010). Investigating how and what prospective teachers learn through microteaching lesson study. *Teaching and Teacher Education, 26*(2), 351-362.

Grossman, P. (1990). *The making of a teacher*. Teachers College Press.

Henze, I. & Barendsen, E. (2019). Unravelling student science teachers' pPCK development and the influence of personal factors using authentic data sources. In A. Hume, R. Cooper & A. Borowski (Eds.), *Repositioning pedagogical content knowledge in teachers' knowledge for teaching science* (pp.201- 221). Springer.

Holden, M. (2022). Exploring online lesson study as a vehicle for teacher collaborative professional learning. *International Journal for Lesson & Learning Studies*, 1-15.

Juhler, M. V. (2016). The use of lesson study combined with content representation in the planning of physics lessons during field practice to develop pedagogical content knowledge. *Journal of Science Teacher Education, 27*(5), 533-553.

Karlström, M., & Hamza, K. (2019). Preservice science teachers' opportunities for learning through reflection when planning a microteaching unit. *Journal of Science Teacher Education, 30*(1), 44-62.

Leavy, A. M., & Hourigan, M. (2016). Using lesson study to support knowledge development in initial teacher education: Insights from early number classrooms. *Teaching and Teacher Education, 57*, 161-175.

Lee, L. H. J., & Tan, S. C. (2020). Teacher learning in Lesson Study: Affordances, disturbances, contradictions, and implications. *Teaching and Teacher Education, 89*, 1-15.

Lertdechapat, K., & Faikhamta, C. (2021). Enhancing pedagogical content knowledge for STEM teaching of teacher candidates through lesson study. *International Journal for Lesson & Learning Studies, 10(*4), 331-347.

Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining pedagogical content knowledge: The construct and its implications for science education* (pp. 95-132). Kluwer Academic Publishers.

Marble, S. (2007). Inquiring into teaching: Lesson study in elementary science methods. *Journal of Science Teacher Education*, *18*(6), 935-953.

Matthew A. d'Alessio (2018). The effect of microteaching on science teaching self-efficacy beliefs in preservice elementary teachers. *Journal of Science Teacher Education, 29(6),* 441-467.

Ni Shuilleabhain, A., & Bjuland, R. (2019). Incorporating lesson study in ITE: Organizational structures to support student teacher learning. *Journal of Education for Teaching, 45*(4), 434-445.

Patton, M. Q. (2002). *Qualitative evaluation and research methods* (3rd ed.). Sage.

Shulman, L. S. (1987). Knowledge and training: Foundations of the new reform. *Harvard Educational Review, 57,* 1-22.

Sims, L., & Walsh, D. (2009). Lesson study with preservice teachers: Lessons from lessons. *Teaching and Teacher Education*, *25*(5), 724-733.

Tsui, A. B. M., & Law, D. Y. K. (2007). Learning as boundary crossing in school-university partnership. *Teaching and Teacher Education, 23,* 1289–130.

Verhoef, N., Tall, D., Coenders, F. & van Samalen, D. (2013). The complexities of lesson study in a European situation. *International Journal of Science and Mathematics Education, 12* (4), 859-881.