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Fostering Teacher Educators' Professional Development through Collaborative Action Research

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Abstract

This study reports on the experience of three novice science teacher educators as their journey on unpacking and scrutinizing their inquiry implementation. In this study, the three science teacher educators formed a critical inquiry group and engaged in collective action research to identify weaknesses and strengths in their instruction of inquiry as they attempted to teach a science laboratory course for future primary teachers and develop new knowledge about how to best promote inquiry in their laboratory courses. For this purpose, the novice science teacher educators engaged in inquiry collaboratively within a learning community to improve their own professional development through a whole semester. Data was collected by use of audio-recorded planning and reflection meetings, written weekly reflections, and pre-interviews and post-interviews with three researchers and final written reflection. Data collection was continuous and spanned through the fall semester of the science laboratory course offered in a primary teacher education course. Analysis of the findings revealed the reflection and the construction of collegial relationship between science teacher educators enabled them to view them as science educators through new lenses. The implications derived from the data, served to inform science teacher educators regarding the professional development of novice science teacher educators through forming collaborations in which they questioned and pursuing the theoretical and practical bases for their practice.

Keywords: Professional Development; Teacher Educators; Inquiry Implementation

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INTRODUCTION

Science educators have made inquiry-based science instruction a priority for classroom instruction since publication of The *National Science Education Standards (NRC, 1996).* For effective science instruction, science teachers need to be able to implement inquiry in their classes effectively (Caps & Crawford, 2013). However recent research showed teachers' challenges while doing inquiry which in turn causing problematical inquiry-based science education experiences (Oppong-Nuako et al., 2015). Pedagogical Content Knowledge (PCK) in the science education literature has attracted considerable attention since the early years of the 21st century. Shulman (1986) described PCK 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'' (p. 8). Hence, based on the PCK definition, science teachers must have knowledge about science along with curriculum, instructional methods and strategies, assessment, and learners to be an effective teacher.

Although there has been considerable research on pre-service and in-service teachers' PCK, there is limited research concerning science educators' PCK. Along with the study of Abell et al. (2009), Osmond and Goodnough (2011) conducted a self-study to examine the instructor's development of PCK and her teaching in the context of an elementary science education methodology course. The study revealed that the self-study research helped the instructor promote her PCK and classroom practice. In another self-study, Faikhamta and Clarke (2013) investigated a novice STE's beliefs and teaching practices in supporting and developing PCK of his students in the context of a field-based science teaching methods course. They figured out that regardless of he held strong PCK in teaching science, his PCK for teaching science teachers was limited, particularly knowledge of instructional strategies and knowledge of assessment of science teachers' learning. Similarly, Demirdogen, Aydin and Tarkin (2015) investigated how re-designing and teaching practicum course developed their, as science teacher educators, pedagogical content knowledge (PCK). They found that the self-study enriched their development of PCK regarding all PCK components.

In sum, all these studies aligned with the claim that novice science educators needed to observe their experience with new lenses to make sense of the meaning of the experience and knowledge to better develop themselves professionally to become more effective science educators.Given this evidence and the continued emphasis on how teacher educators themselves enact their own PCK , calls for the need to better scrutinize and develop new understandings, and models for the preparation of future primary teachers. Motivated by this call, three teacher educators engaged in a collaborative action research project to improve the quality of laboratory science instruction in their laboratory courses. The questions pursued in this inquiry was:

In what ways engaging in collaborative action research help science teacher educators' professional development related to teaching science through inquiry to pre-service primary teachers (PPT)?

Review of Relevant Literature

The necessary professional knowledge base for science teacher educators (STEs) have been questioned and studied by few science educators (Osmond & Goodnough, 2011; Wiebke & Rogers, 2014). Abell et al. (2009) questioned the standard doctoral education curriculum and argued that as currently practiced most doctoral programs do not provide sufficient and meaningful experiences for future teacher educators to become good teachers. Based on their experiences both as doctoral students and teacher educators the authors proposed a model for the development of PCK for teaching future science teachers. The model suggests a continuum of professional learning in which STEs become observers, apprentice, partners, independent instructors, and finally mentors respectively. They argue that all of these experiences can help future STEs to develop pedagogical content knowledge for preparation of future primary teachers.

Wiebke and Rogers (2014) also investigated a STE's tensions and how that influenced STE's orientations towards teaching primary teachers about lesson sequencing through self-study. Data were gathered through pre-service teachers' artifacts, an audio-recording of the preservice teachers discussing the planning of their lesson sequence, and two reflection journals, one kept personally, and one kept collaboratively with her co-author and critical friend. Although she was trained as an observer, apprentice, and independent instructor as in the model suggested by Abell et al. (2009), she experienced tensions of telling and growth developed gradually, confidence and uncertainty, and planning and being responsive. More specifically, she experienced tension "between acknowledging student teachers' needs and concerns and challenging them to grow" and "between informing and creating opportunities to reflect and self-direct" (Berry, 2007, p. 1313 as cited in Wiebke & Rogers, 2014). For instance, she particularly struggled "between informing the pre-service teachers what to focus on when looking at each instructional tool and allowing them to construct their own ideas about how the tools are used collectively to make lesson planning decisions" (p. 230). In terms of the confidence and uncertainty aspect, the authors reported that lack of confidence and uncertainty due to poor planning made her uncomfortable and worried about "confusing the preservice teachers further about the lesson planning process by portraying her own pedagogical conflicts" (p. 233).

Findings reported in these studies collectively suggest both the importance of engaging novice pre-service teacher educators who have limited experience with preparation of future primary teachers in critical reflection and the impact of such reflection on their growth as teacher educators. Moreover, very few studies concerned how such practices best support teachers' educators professional development (Wiilemse, Boei & Pillen, 2015). Considering the few studies have reported the transition of science educators' to be an experienced science educator, it is important to know how best these science educators could be supported to best reveal their potential for growth in enactment of inquiry-based teaching. Keeping in mind, challenging owns' beliefs and assumptions related to teaching lead to professional growth (Donohue at al. 2020), collaborative action research might serve to the professional growth of teachers. Informed by these studies and motivated by the urgent need for improvement, three STEs engaged in collaborative action research to develop pedagogical capacity to teach science through inquiry in a laboratory course offered for pre-service primary teachers. We reported on the impact that such collaboration including reflection designed to improve their teaching had on STEs' professional development to teach science through inquiry.

Theoretical Framework

The theoretical framework guiding this inquiry is a critical inquiry enacted in the form of collaborative action research project. Collaborative action research provides a context in which professionals are active agents in questioning and pursuing the theoretical and practical bases for their decision-making and practice (Cunningham, 2011). Collaborative action research is both collaborative and participatory. Daly (2007) states that participatory action research "is concerned with the generation of practical knowledge that can serve people in the process of transformation" (p. 120). Dominated by a critical and reflective discourse, participatory and collaborative action research can foster the co-construction of new pedagogical stances, knowledge, and skills that can effectively address the complex challenge of bringing about change in teacher education.

It is within this framework, the three STEs formed a critical inquiry group and engaged in collective action research to identify weaknesses and strengths in their instruction of inquiry as they attempted to teach a science laboratory course for future primary teachers and develop new knowledge about how to best promote inquiry in their laboratory courses. In that sense, STEs came together weekly, unpacked their understanding of scientific inquiry as well as practice, scrutinized their discomfort and challenges through their teaching and reflected on their teaching experiences in the aim of learning each others' experiences and professional growth.

METHOD

Context of the Study

As a result of the acceleration of the improvements in science and technology in the new millennium, the renewed science curriculum in 2005 was developed with a constructivist approach in Turkey. In the curriculum, emphasis has been placed on student-centered and activity-based implementation. The curricula put scientific literacy at the center of it. The vision of the curricula was "educating all students as science literate individuals" (Ministry of National Education, 2005, 2013). Therefore, curriculum stresses the nature of science, scientific inquiry, and science process skills. Additionally, it was highlighted that learning environments should be designed according to inquiry-based. The science courses, which begin in the 3rd grade of primary school aims not only to give basic information about astronomy, biology, physics, chemistry, earth and environmental sciences and science and engineering applications, but also to adopt science process skills and scientific research approach as well as to understand nature of science through inquiry-based teaching.

The study was undertaken in the context of the science laboratory course given in the primary teacher education course in three midsize teaching focused universities in Turkey. Through the primary education course, undergraduate students were offered a variety of science courses regarding science such as fundamentals of physics, chemistry and biology through the first two semesters of the teacher education program among the 8 semesters in total. The science laboratory course was offered in the third semester of primary teacher education program and it was a mandatory course. The aim of the course was to improve science process skills in setting up experiments in science courses for the primary level kids ranging in age 7 to 11 years old. Moreover, it aimed to improve cognitive abilities such as critical thinking, problem solving, enhance attitude such as preservation, curiosity, interest, confidence towards science. In addition, it also proposed development of basic concepts in science as well as development of understanding in nature of science views, scientific enterprise, and scientific inquiry. For that purpose, three science teacher educators collaboratively designed and implemented a science laboratory course consisting of aforementioned components but also embracing reflection as another main component of the course. Through this collaboration of designing the science laboratory course three science teacher educators reflected on and shared their practice, experiences, and pedagogical work. Within this collaborative activity, three of the science teacher educators monitored and explored the contribution of the collaboration on the change in their teaching practice and teaching philosophy.

Design of Communities of Inquiry as a Mean of Professional Development Activity

Communities of inquiry was designed to foster STEs' professional development to improve teacher education. The features of communities of inquiry within the teachers' professionalization domain characterized features of current study aiming to contribute to practice of science teacher educators. Three science teacher educators (STE) engaged in inquiry collaboratively within a learning community to improve their own professional development through a whole semester. First, three researchers wrote their teaching philosophy, stated goals of science laboratory course from their own perspective to compare and contrast their standpoints regarding science laboratory course. Keeping in mind that all three STEs completed the same PhD program at same university, and had similar learning and teaching experiences, their teaching philosophies and goals came up to be similar. Then, each STE took the responsibility of designing three inquiry- based laboratory activities related to different science concepts. The content of each inquiry activity was decided based on the K-4 science curriculum. After designing each inquiry-based laboratory activity, each STE examined the activities regarding having appropriate components of inquiry and science content. Additionally, an online meeting was arranged to discuss the appropriateness of activities both in terms of inquiry and the science concepts targeted in the lesson. After getting feedback on each activity the activities were re-designed. In that phase of the research, all STEs assured the designed activities were inquiry-based and embraced with reflection component. Then each activity for each week was designed as laboratory sheets which guided PPTs during the inquiry-based tasks. Each laboratory sheet included the aim of the task, short science content background information related to task, guiding questions and reflection questions related to task. After the design of reflective inquiry-based activities, STEs kept collaborating during the implementation of these activities in their science laboratory courses. Through the semester they engaged in audio-recorded weekly meetings in which they reflected on implementation of activities in addition to the written reflection papers. Each meeting was scheduled 5 times through the whole semester and lasted about 1 hour. In each meeting, they shared their experiences regarding the strength and weakness of the implementation of each activity, students' engagement of activity and alternative ways to promote students' engagement in tasks. The main concern of each meeting was to ensure the sharing of the best practices of reflective inquiry activities as well as to ensure the best implementation of each reflective inquiry-based activity in the science laboratory course.

Participants

Participants of the study were three female STEs who completed their PhD in science education program at the same university. Two of the STEs completed their PhD one year and the other one had completed her PhD three years before the implementation of this study. All STEs had experience in research related to the nature of science, inquiry-based science instruction, and pre-service primary teacher education. They had strong motivation in pursuing excellence in research and teaching as well as preparing future primary teachers.All the participants voluntarily aimed to shed light on their teaching experience to improve themselves professionally. Therefore, all STEs explained the aim of the research to their students enrolling the course which the data was collected. They were informed that no data related to their performance, views related to the course would be collected either used in current study.

Data Sources and Data Collection Methods

Several data sources were used to develop a richer understanding into these STEs' pedagogical practices, the nature of their reflection, and how this reflection informed their thinking regarding inquiry-based instruction. Data consisted of transcriptions of audio-recorded planning and reflection meetings, written weekly reflections, and pre-post semi-structured interviews with three researchers and final written reflection. Data collection was continuous and spanned through the fall semester of the science laboratory course offered in the third semester of primary teacher education program.

The interviews focused on the areas of professional development of the STEs as well as the characteristics of communities of inquiry contributed to the development of STEs. To identify change in professional development, the STEs were asked to share their experiences while designing and implementing inquiry-based laboratory activities in audio- recorded weekly meetings. The meetings were framed by issues such as suggestions to improve the implementation of inquiry-based laboratory activities, suggestions on how to engage students better, what content knowledge should be integrated into the activity and what components of the activity needed. Similarly, in written reflection papers researchers had a chance to reflect on their practices and shared their best part of implementation as well as failures. Moreover, they also noted the missing parts of the implementation that should be revised in the first place. Furthermore, in final interviews with the researchers, and in their final reflection papers, they were encouraged to describe whether participating in communities of inquiry contributed to their professional development.

Data Analyses

Considering the nature of qualitative research; the main data sources used to explore research questions were the pre-post interviews of three STEs', audio record of weekly meetings and written reflections of the researchers followed by each teaching session as well as at the beginning and outset of the intervention. All interviews and weekly meetings records were audio recorded, transcribed and member checked (Merriam, 2002). The analysis was undertaken by adopting the general approach specific to qualitative research. This approach embraced writing reflective notes in passages, drafting a summary sheet, writing codes, creating patterns and themes, counting for frequency of codes, relating categories, and making contrast and comparisons (Miles &Huberman, 1994) Besides, research question was used as sensitizing concepts for further development of categories in addition to the development of categories emerged from the data (Patton, 2015). Analyzed and coded interviews and weekly meeting notes were compared and differences in interpretations were resolved by reanalyzing and category adjustment until consensus was reached (Patton, 2015). Analysis was done by the first author of the manuscript as well as another outsider researcher who is very experienced in science education research. Each participant was represented anonymously as *STE I, STE II* and *STE III*.

RESULTS

The data was analyzed to investigate the collegial relationship emerged from collaborative action research of STEs to promote pre-service primary teachers (PPT)' engagement with inquiry and their pedagogical development as a result of this collegial relationship. The results are organized and reported in five different subtitles, reflecting the themes emerged from the findings. These include: 1) planning for effective student engagement, 2) addressing lack of students' prior content knowledge, 3) scaffolding classroom discourse/discussions, 4) addressing students' data analysis and interpretation skills, 5) evolution of STEs teaching.

Planning for effective student engagement

To identify change in their professional development the STEs were asked to share their experiences while designing and implementing inquiry-based laboratory activities in audio- recorded weekly meetings as well as in written weekly reflections. One of the main concerns of the STEs regarding implementation of successful inquiry laboratory applications for PPTs were focused on improving PPTs' engagement with inquiry-based laboratory tasks. For this purpose, the STEs monitored the structure of inquiry laboratories and carefully re-examined the components of the course that contributed to the PPTs' engagement with laboratory tasks. Promoting PPTs' meaningful involvement in inquiry was generally associated with increasing PPTs' motivation and performance through giving feedback related to their performance on inquiry-based tasks. The STEs found out that giving feedback positively affects students' involvement in laboratory tasks. For instance, one of the STEs mentioned informing all individuals one by one on their progress on the task instead of giving general feedback to the whole class regarding the mistakes or missing parts that the majority of them done. She pointed out specifically the parts of the laboratory sheets requiring improvements as well as the grades they get from each week's laboratory task. By providing this specific feedback, students paid more attention to the details and became more reflective in their laboratory reports.

> *STE II: Previous weeks, I pointed out the parts that the majority of my students struggled with understanding. After evaluating the causes of their mistakes, I realized that they need more clear directions. I tried to be clearer with my directions and check on them constantly, and support them to make sure that they are meeting the* laboratory *goals and engage in inquiry-based learning. I guess my constant attention and guidance motivated them (PPTs) to pay more attention to the subsequent laboratory.*

One of the STE mentioned that she specifically pointed out that when she read each laboratory report of students she provided personal feedback, and students responded more positively to her instruction and more effectively engaged in the laboratory activities. She noted that providing that kind of specific feedback helped PPTs recognize their instructors' investment in their learning. This recognition and appreciation consequently increased their motivation to learn for pre-service teachers. Additionally, she indicated that, providing feedback motivated them to put more effort into their thinking, the content and organization of their laboratory reports:

> *STE III: I personally read each week's* laboratory *report and gave my students specific comments regarding their answers to the* laboratory *questions. The PPTs are very happy about it, because they think I care about their learning. Thus, they want to please me, impress me with their performance in the* laboratory. *That increases their motivation to learn more rigorously the content of my course.*

Moreover, the nature of feedback was found to be influential on PPTs' performance on inquiry-based tasks. For instance, one of the STE stated that she gave immediate feedback to each group regarding their performance on inquiry-based laboratory activity. Knowing that PPTs had limited prior knowledge of the science content related to the inquiry task, she provided feedback related to the content as well. She stated that she monitored each group's task engagement, provided some further questions related to the task and content knowledge related to the laboratory, then she gave them the opportunity to show their knowledge, which gave the PPTs the opportunity to know whether the students were on the right track or they needed more support. Based on the feedback gathered through this close monitoring, the PPTs were able to look back at the activity and revise some parts both to make students more effectively engage in inquiry and to help them acquire the scientific content more effectively. She stated that in later weeks, students in groups started to demand more specific feedback from the instructor then they completed the task after they got an idea on their progress. Particularly, they expected to be checked on to make sure if they did everything expected of them, and to be asked how/why questions related to the content:

> *STE I: I am giving immediate feedback while they [PPTs] are working on the inquiry-based tasks. I will go to visit each group and tell them things like "you are doing great, you need to look over the content again, or I don't think you truly understand the task you are working on, what is your goal?" After a while, the students themselves seek that kind of feedback. If I forget to check on their progress while they are working on the inquiry tasks, or provide feedback on their* laboratory *reports.*

Another interesting theme that emerged from findings was related to students' attitudes towards inquiry-based laboratories and how that increased their engagement over the course. All of the STEs were aware of PPTs' negative attitudes towards laboratory sessions. Common issues related to laboratory sessions included, fear of inquiry-based science, reluctance to attend the class at the outset of the laboratory courses, and failing to submit quality laboratory reports. However, at the final meeting all of the STEs reported changes in PPTs' attitudes towards laboratories.

> *STE III: One of the things that I liked to hear during the interviews with PPTs is how they liked the laboratory sessions. One of the PPT said, "I was afraid of science laboratories, although my grade [midterm grade] is low I do love the class. I learned that there is nothing to be afraid about doing* laboratory *experiments." That is a great thing for me to hear.*

In summary, all STEs raised concerns regarding students' attitudes towards laboratory and inquiry-based science laboratories more specifically at the beginning of the semester and how that changed as a result of their PPTs efforts to help them more effectively engage in inquiry-based laboratory activities.

Addressing lack of students' prior content knowledge and skills,

Another issue that was discussed during the weekly meetings was tailoring instruction to students' prior knowledge and experiences with inquiry. All the researchers noticed PPTs' lack of experiences related to inquiry for first weeks starting from the first weeks of the laboratory. During the weekly meeting discussions, the main issue raised by the STEs was the fact that many PPTs lacked content knowledge and experiences with inquiry. As a result, the STEs noticed that many PPTs were not able to perform experiments or engage in inquiry tasks properly.

> *STE II: ... they [PPTs] do not study the required science content knowledge before the* laboratory *enough, as a result, they have difficulties in making connections between the laboratories they are doing and the related content knowledge. I observed this problem specifically during the three-hole bottle activity; the only important thing for them [PPTs] while doing the task is to squirt the water inside the bottle out.*

To help PPTs to overcome such difficulties, STEs mentioned that they need to use different instructional strategies such as giving extra information related to content or some probing questions for addressing the lack of content knowledge and skills prior to the laboratory. All the researchers agreed on giving extra clarifying information related to the laboratory tasks and content knowledge at the beginning of the laboratories which inhibited meaningful discussions and students' involvement in inquiry:

> *STE I: one of the major handicaps we have for the implementation of inquiry-based tasks is PPT's lack of content knowledge and their lack of preparation for the* laboratory *tasks. For instance, they [PPTs] do not have a basic understanding of the concept of pressure, therefore, I could not facilitate as many whole- class or group discussions as I wished to do. For that reason, we need to give more detailed information related to basic concepts such as air pressure, gas pressure in our laboratory sheets.*

> *STE II: ...Same here, they [PPTs] do not know the concept of the pressure enough, because of lack of knowledge, they are not able to make fruitful discussions. Therefore, I realized that we need to revise the* laboratory *sheets and such that we need to add more concepts related to pressure.*

The STEs also reached a consensus on providing some probing and guiding questions to explain some key concepts related to the task and the content of the laboratory activity in addition to adding some more detailed content info in the laboratory task sheets. Correspondingly, one of the researchers defined her success in later laboratory activities because of posing critical and guiding questions, providing extra examples from daily life, having time for discussion, elaborating the laboratory tasks with some extra activities. Collectively, these instructional activities, helped the students to make connections between the scientific content and the inquiry-based task for PPTs:

> *STE II: [an activity related to acid and bases] ... since I have PPTs who have done these tasks for several times, I started with questions to make them think before the start of the task. I asked them questions related to daily life such as why there has been a color change in salad if there is a red cabbage in it? What red cabbage refers to in a color scale acid or base? Or think of the soap? Did you ever taste it, how it tastes, what you think of its taste, is it an acid or base? Why?...*

In sum, these comments and ideas emphasized the importance of students' prior science content knowledge and how it prevents students' effective engagement with inquiry. In addition, they highlighted the importance of helping students to make connections between the science content and the purpose of the inquiry tasks.

Scaffolding Classroom Discourse/Discussions

Improving exploration and PPTs' thinking through inquiry were other concerns of the STEs involved in this study. They stated that one of the major drawbacks of the laboratory session was lack of time for discussion. All the STEs used questioning to guide and scaffold the discussion environment fostering elaboration on the target concepts. For instance, one of the STEs noted that when she provided probing and guiding questions, the laboratory sessions proved to be more fruitful and meaningful for the students:

> *STE I: This week I had a very successful* laboratory *session. I guess the reason for that success is that I mostly led them with guiding questions and elaborated on the content through examples instead of giving them direct answers. I also let them elaborate on their observations and results. .... They [PPTs] drew meaningful conclusions based on the experiment. There has been more questions and discussion as a result of my guiding questions…*

Addressing Students' Scientific Inquiry Skills

Promoting PPTs' science process skills has received attention of STEs' through weekly meetings because of the poor performance of PPTs' at initial laboratory sessions. After realization of PPTs' deficiency in using science process skills (SPS), the STEs started to highlight SPS specifically in laboratory sessions through the inquiry-based tasks such as they specifically asked PPTs to label the scientific skills used in each task which lead an increased performance of PPTs in using SPS within inquiry-based tasks. In addition to improving PPTs' understanding and practice of basic SPS such as observing, predicting, measuring, the researchers aimed to develop PPTs' understanding of and skills in designing controlled experiments. For instance, all the STEs addressed the PPTS' difficulties regarding concepts of dependent, independent variables, and hypothesis testing:

> *STE II: They are struggling with writing hypotheses. Even after I provided a couple of examples of dependent and independent variables, they still were not able to differentiate between independent and dependent variables. They have no idea how to write a hypothesis or what is a dependent, and an independent variable…*

Consistent with this, one of the STEs stated her satisfaction with PPTs' use of science process skills, that she noted that she felt successful regarding PPTs' performance with SPS. She stated that they could integrate these skills in their designed experiments even when the task did not specifically require them use these skills:

> *STE II: [related to task included designing an experiment] The thing I like related to this week's* laboratory *is that while they are designing an experiment they included questions like "write your prediction" , "your observation and predictions are different or similar". Write your hypothesis, label the dependent and independent variables" .... At that point, I felt I succeeded. Now they [PPTs] can integrate and use SPS, even though the task did not require them to specifically use those skills, SPS make sense for them.*

Evolution of Teaching

In addition to the weekly reflections and audio recorded meetings STEs also chance to share how this collaboration and reflection experiences contributed to their teaching. They stated more precisely how their teaching evolved through this collegial relationship revealed through analysis of audio records and written artifacts. First, regarding their teaching philosophy, they all stated similar goals that they wanted to achieve for PPTs at the end of the laboratory course. They all expressed that they wanted the PPTs to have positive attitudes towards science laboratory in their final reflections.

Additionally, they also wanted students to gain science process skills and ability to design and conduct basic science experiments for their future students:

> *STE I: My main goal in this course is to teach basic science concepts to PPTs. Additionally, I want pre-service teachers to understand basic features of scientific inquiry as all the* laboratory *activities which are reflective inquiry-based activities. As a teacher and researcher, I want all pre-service teachers to understand and transfer their understanding of inquiry into their teaching. I also want them to understand and apply the science teaching strategies promoted in current science education documents.*

Regarding their perceptions of success and failures of their performance as an instructor in their laboratory course; they all found themselves successful in teaching SPS, and getting them doing basic inquiry-based activities as well as improving their attitudes towards laboratory:

> *STE II: ….They will most likely be able to write hypotheses, and variables of the experiments correctly. Related to their attitudes, I am not sure, but some of the students told me that they had been afraid of this course at the beginning but now they were not afraid of any more after they saw what they could do. Some of them also told me that they wished other courses would have been like the laboratory course*

When they were asked how collaboration contributed to their success in the laboratory, one of the researchers emphasized the "reflection" component of the collaboration. She stated that collaboration utilized reflection on each researchers' teaching which enabled them to draw attention of strengths and weaknesses of themselves regarding what to do or not to do for the next lesson:

> *STE I: Having the opportunity to reflect on my classes made me self-monitor my own teaching. Then I started to be aware of my own teaching which made myself give more attention to my teaching for the next classes related to teaching strategies that I used. For instance, I started to pay more attention to the issues such as covering SPS or spending more time for student discussion in class. Consequently, I started to be aware of strengths and weaknesses of my teaching. It was like self-monitoring my teaching in that sense...*

The other important component of collaboration contributing to their development was stated as sharing of experiences, failures, and success. That kind of sharing was claimed to be beneficial for becoming aware of students' prior knowledge and correspondingly their ability to pursue the inquiry tasks, the important content knowledge needed to be emphasized, better engagement of students in laboratory tasks and possible challenges faced in doing tasks revealed through answers in interviews and written reflections. For instance, at the final interview one of the STE stated that sharing of experience at weekly meetings lead her to monitor her own teaching related to her professional improvement as well as students' improvement:

> *STE I: Based on my colleagues' experiences, I knew which part [regarding content] I needed to highlight more. Additionally, their[colleagues'] reflection related to students' prior knowledge, the parts [regarding tasks] needed to be covered more deeply made me motivated towards teaching. For instance, I had not paid attention to students' prior knowledge at the beginning that much, but the meetings made me consider their prior knowledge more carefully…Moreover, at the weekly meetings we had a chance to remind ourselves of our successes related to teaching. Which made me monitor my professional improvement and my students' academic improvement.*

Similarly, in the responses provided through written reflection, STE III explicated that based on these weekly meetings, she started to analyze her own teaching too and paid more attention to instructional strategies to increase students' meaningful engagement with the tasks**:**

STE III: Another contribution to my teaching is that after weekly discussions I started to plan my laboratories more purposefully, and monitor myself while teaching. For instance, I used to pay attention to students' responses less. After our weekly discussions, I started to build on students' responses and engaged all students in learning…Exchange of experiences helped improve my ability to answer students' questions.

The main issues that they perceived themselves as ineffective was highlighting content knowledge properly. One of the STE mentioned time limitation to cover content knowledge enough during the inquiry -based tasks:

STE II: I was not able to spare enough time for content knowledge, since I wanted to focus on SPS for each experiment tasks. Therefore, I was unsuccessful in covering enough content knowledge. Time limitation was the main obstacle to talk about content knowledge itself. However, I could have highlighted content knowledge more while I was checking the groups during classes.

As pointed out earlier, only one of the researchers defined lack of NOS emphasis as a weakness of her instruction:

STE I: My effort to emphasis NOS was only my personal effort to make them[PPTs] aware of NOS issues After a while it was hard to emphasis NOS through the experiments, since we had not planned teaching NOS explicitly.. I totally agreed the statement from literature that perceived NOS as a cognitive outcome that should be planned...

Overall, reflection and collegial relationship built between the researchers enabled them to scrutinize their teaching pedagogy about failures and success. In that sense, development of collegial relationship and reflection opportunities assumed to help their ability to design and implement successful inquiry lessons as well as use of other innovative pedagogical approaches (e.g. raising questions, nature of science instruction).

DISCUSSION

There has been an increasing emphasis among STEs to prepare future teachers to teach science through inquiry. Consequently, there has been an effort to reform both in-service and pre-service primary teacher education curriculum, so they have a solid understanding of and sufficient experiences in inquiry-based instructional strategies. However, relevant research reported failure and inefficiency of science teachers in implementing inquiry in their teaching (Capps, Crawford, & Constas, 2012) due to their lack of and underqualified experiences related to inquiry (Gillies & Nichols, 2015). Similarly, for a pre-service primary teacher to develop capacity and efficacy to teach science through inquiry, they must have quality experiences with inquiry-based teaching. Therefore, both pre-and in-service science teachers have been needed to be provided with better and meaningful inquiry-based teaching experiences during their science teacher education programs. In this study, a group of STEs engaged in a collective action research project to provide their students with qualified inquiry experiences in the context of a laboratory course. The results show that STEs could align their laboratory course with inquiry as a result of their reflections that took place on a weekly basis. Building on the feedback received from their students' observed participation and performance in the laboratory, STEs were able to identify problems related to students' prior knowledge with related science concepts and science process skills. Consequently, they were able to tailor their instruction to students' learning needs. Aligned with Willemse, Boei and Pillen (2015), conducting such research enabled the researchers to scrutinize and improve their own practice in a systematic way which led to their professional development related to inquiry implementation. More specifically on their inquiry instruction, they provided more scaffolding, they asked guiding questions to help their students to establish meaningful connections between the laboratory tasks and the content related to the specific laboratory task. They learned to encourage their students to more effectively ask questions, to write better and meaningful laboratory reports and provide more elaborate responses. Moreover, the STEs were able to understand the importance of group-based and whole-class discussions and facilitate such discussion at the end of each laboratory. While not all of the STEs were able to successfully integrate NOS into their instructions, they were able to develop instructional plans for the subsequent instruction. This form of collective inquiry into lesson planning and reflective action on instructional practices encouraged STEs to question their instructional and assessment practices for the purpose of making their lessons more inquiry-based. As proposed by Donohue, Buck and Akerson (2020), looking closely to the area where discomfort and uneasiness occurs was the place of beginning for the professional growth for the STEs. As a result of this reflection, they were able to re-design their learning tasks, provide more focused guidance, and ask more purposeful questions to make students' learning experiences go beyond the laboratory and focus more on thinking like a scientist. Reflection was presented as a crucial part of professional development that hinder or facilitates professional development (Vanassche & Kelchtermans, 2016). Moreover, definition of effective collegial environment included share of practice for growth in a reflective, inclusive, collaborative manner (Stroll et al., 2006).

One of the reasons for the development in teaching of STEs might be due to the nature of collegial relationship built during the weekly meetings. All three STEs could build a confident mutual relationship which all benefited their weaknesses and strengths regarding teaching since all they were teaching the same subject. Consequently, Smith (2003) suggested that professional team work, with members sharing similar practices and with small group sizes were better to contribute to teacher educators' professional development. In the current case, the researchers could be able to share their experiences related to similar practices in a non-judgmental friendly and supportive atmosphere. Additionally, the size of the group work also provided equal opportunity for each STE to learn and share their similar experiences which also indicated practical examples for individual professional development initiative (Murray, 2010; Willemsie, Boei & Pillen, 2015). Additionally, Kosnik et al. (2015) stated that professional development would be improved by communities of inquiry in which "groups of people who share a concern, set of problems, or a passion about a topic and who deepen their knowledge and expertise". Aligned with Kosnik et al., (2015), involving in collaborative action research enabled researchers to better develop their pedagogical and theoretical knowledge related to inquiry implementation. In sum, keeping in mind that many researchers agreed to define professional development as a reflective practice contributing to individuals' knowledge, attributes and skills (Dengerink, Lunenberg & Kools, 2015; Early& Porritt, 2010; Kosnik et al., 2015), engaging in such collaborative inquiry enabled STEs to develop their skills, knowledge and practice relate to inquiry implementation.

Implications

According to the findings, a lack of prior content knowledge and skills were a barrier for PPTs' to engage in inquiry tasks well. Scaffolding classroom discourse overcame this problem. Hence, asking critical and guiding questions, relating the content to daily life, and creating a learning environment which involved discussion are suggested to promote this. Motivation and attitude are other important factors for effective student engagement in the laboratory that students should be given positive feedback and feel supported.

As the inquiry becomes a critical goal in teacher education, STEs, who were educated through traditional teaching methods must develop conceptual understanding and pedagogical capacity to teach science through inquiry. The findings of the study revealed that professional growth of science educators is a very important and ongoing process and it should be supported especially for the novice science educators. In that sense professional development by means of collaborative action research might help science educators to unpack and improve their understanding and practice inquiry implementation. However, rarely do STE engage in such collaborative inquiry. This is the case because each PPT comes to the discussion table with unique experiences, diverse ways in which students engage in inquiry, struggle while doing inquiry and successfully engage with inquiry. This diversity helps STEs not only to develop a repertoire of problems that may occur while conducting inquiry-based laboratories, but also of solutions to address those problems. We encourage STEs to engage in such collaborative action research projects if the goal is to increase pedagogical capacity to teach reform-based science.

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