

Development of Scientific Literacy and Pedagogical Content Knowledge (PCK) of Prospective Science Teachers through Lesson Study-Based Courses

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Abstract: Lesson Study has been adopted as an effort to improve the quality of education in many countries. Scientific literacy and pedagogical content knowledge (PCK) are two indicators of quality education which most agree are important considerations for science teachers this research has been undertaken by following a lesson study-based action research intervention. The objectives were to analyze its effects on development of prospective science teacher (PST) scientific literacy and PCK indicators. Research subjects were 32 fourth semester PSTs enrolled in Strategies for Teaching Biology course. The research was conducted in three cycles with a plan-do-see phase in each cycle. The data were obtained from PSTs' tasks and analyzed by comparing the mean score gained for two indicators of scientific literacy and three indicators of students' PCK. Results of this study indicates that the mean scores gained in each indicator of scientific literacy and PCK were higher in the third and second cycles of lesson study when compared to the first cycle. Therefore it can be concluded that implementing lesson study based action research brought about improvement the PSTs' scientific literacy and PCK, as well as the quality of teaching and learning processes.

Key words: lesson study; scientific literacy; pedagogical content knowledge

Introduction

One of the main purposes of science education is to educate scientifically literate citizens (Roberts, 2007). In the process of developing scientific literacy of the young Indonesian society, science teachers have an important role. The capacity of science teachers to help students construct knowledge and skills depends on the blending of content knowledge and pedagogical content knowledge (Aydin & Boz, 2012, Chapoo, et al, 2014). This means that those involved in supporting the professional learning of PSTs, need to identify ways to continuously consider effective ways to develop their scientific literacy and pedagogical content knowledge (PCK) (NEA, 2010). In 1986 Shulman proposed that PCK is the representation of content and pedagogy blended into an understanding of how particular topics of subject matter are organized and

represented in adaptations that take into account the diverse interests, abilities, and needs of learners as the topic is presented for instruction (Criu & Marian, 2014). Given this, Jing-Jing (2014) identified five main components of science teachers' PCK which includes (1) science learning experiences that include student-centered activities, discovery, inquiry, and project-based learning, (2) knowledge of science curriculum, (3) knowledge of students' understanding, (4) knowledge of teaching strategies, and (5) knowledge about assessment of students' learning outcomes. In the end, PCK forms a knowledge base for teachers, guiding their decisions and actions in classrooms. In other words, teachers' PCK play an important role in enhancing the quality of learning outcomes, mastering subject matter, and develop students' scientific literacy (Ekitna, 2010; Loughran, et al., 2012). Regarding the importance of teachers' PCK, it can be concluded that supporting its development by pre-

service and in-service science teachers should be a major focus of those engaged in supporting teacher professional learning (e.g., university science educators).

Previous research in Indonesia has revealed the importance of a focus on science literacy with PSTs (Jufri et al., 2017; Sujana, et al., 2014; Fakhriyah, et al., 2017), especially related to supporting the PSTs' critical thinking (Slamet et al., 2014), scientific reasoning (Jufri et al., 2016), and PCK (Jufri et al., 2017; Nurmatin & Purwianingsih, 2017). This previous research reveals the importance of a concerted focus by professional developers and university faculty on developing PSTs scientific literacy competences and PCK. Concerning this, Bektas (2015) recommended that science teacher education programs highlight instructional strategies to improve pre-service science teachers' PCK. Given this and in connection with the previous research (e.g., Jufri et al., 2017) and recommendations (i.e., Bektas (2015)), it is necessary to identify, design, and further develop innovative and sustainable efforts that will develop the PSTs facility related to scientific literacy and PCK.

One approach for developing the PCKs of PSTs which has proven to be effective is lesson study (Susilo, 2009; Aryulina, 2010, Lewis & Takahashi, 2013; Lucenario, et al 2016). Lesson study is a model for improving the professional competencies of educators and the quality of teaching and learning processes that has been examined and proven successful in Japan and adopted in other countries worldwide (Dudley, 2015). It has been shown to promotes teacher professional learning through (1) encouraging students to improve professionalism through collaboration, (2) offering a process of cultivating student learning motivation, (3) encouraging students' thinking through classroom observation, and (4) eliciting new perspectives on learning and teaching. Moreover, implementation of lesson study in teaching and learning processes bring about positive effect on development of students PCK competencies, student achievement, students attitudes and perceptions about professional learning opportunities facilitated with lesson study (Lucenario, et al 2016; Kanellopoulou & Darra, 2018). Consequently, the objectives of this study were to analyze the development of PCK and the quality of scientific literacy of prospective student teachers in the Biology Education Program facilitated by the Faculty of Education and Teacher Training in University of Mataram Indonesia.

Method

This study has been setup as a lesson study-based action research that was undertaken during the even semester of academic year of 2016/2017 in the Biology Education Department of Mataram University. The subjects of this research were the 32 fourth-semester students who joined the course of Strategy for Teaching Biology. There were 24 women and 8 men with the average age interval of 20-22. The timeline of the research was divided into two main stages.

The first stage involved the team of lecturers practicing the theory and implementation modes of lesson study. The focus of this stage was to expose participating students to the course materials which were designed and implemented by the team of lecturers through lesson study cycles. During this stage of the course, the model lecturer presented the course materials and introduced the practice of lesson study to the participant students. The mode of lesson study introduced consisted of three cycles that included the planning stage (plan), the implementation stage (do), and the reflection stage (see), aligned with how lesson study is usually practiced in Indonesia (Susilo, 2010).

The second stage of the course was designed to involve students in working in groups through the plan, do, and see phases of the lesson study cycles. Each group was asked to *analyze* one or two basic competences of secondary school science standards, *design* how to teach the content, *develop* a lesson plan, and *evaluate* their skills to practice teaching the content in their groups. These analyze-design-develop-evaluate activities are referred to as Karankemuji, the acronym of *kaji-rancang-kembangkan-uji* in Indonesian language.

This stage was repeated in three lesson study cycles. In the plan phase of lesson study, the students worked in collaborative groups of four-to-five students as they were exposed to the content standards of science in junior high schools. They were directed to analyze at least two basic competences of the science standards and then define or identify essential concepts, and develop concept maps detailing the content of the basic competencies they analyzed. The tasks, which were completed by each student in their group in this step consist of: (1) identifying and presenting essential concepts in the form of concept maps, (2) formulating learning objectives concerning the basic competencies, and (3) writing a mini-lesson plan in which they stated the strategy and argued for the reason they chose to teach the content. The implementing phase of lesson study was focused on

facilitating students in their group to practice their facility in microteaching to present their tasks and try to teach the content. During this phase, one or two students in each group played the role of a teacher model, while the other students took on the role of the observers of student activities. In the final stage (i.e., the see phase) of lesson study, the students were asked to discuss the learning activities of the other students when those students acted as a teacher for them. The discussion was focused on supporting the observer students to talk and present what they recorded during the observations. In this process, one of the lecturer lead the discussion activities.

To collect data related to the scientific literacy of the PSTs scoring rubrics were used to score the concept or mind maps, which include their descriptions of content knowledge produced by student. Indicators of scientific literacy used in this study included students' knowledge of science concepts, and their scientific competencies. Additionally, rubrics and observation sheets were used to collected the data about students' PCK, based on three indicators which included the student orientation to teaching science, knowledge of teaching strategies, and knowledge about assessment. Finally, data analysis was performed by comparing the students' average score for each indicator of scientific literacy and PCK in each lesson study cycle they involved in.

Result and Discussion

This research was undertaken through the course of *The Strategies for Teaching Biology* in three cycles. The first stage of the study was completed during the initial four weeks of lecturing. The lecturer team planned the activities based on three questions as stated by Eggen & Kauchack (2012), namely: 1) What are the important things to learn by prospective teachers related to learning strategies? 2) What do you need

to know and what should you do? And 3) How do you facilitate the learning process so that your future students know the important things you intend, as well as what they should do? These questions served as the framework to develop teaching scenarios and learning aids. The learning tools prepared in the plan phase of each lesson study cycle, consisted of teaching scenarios, and student worksheets. The initial documents were then discussed together with the two members of lecturer team, along with an observer other than the research team. During the primary discussion, there were some agreements between the team, such as the need to modify and improve the quality of the teaching scenarios, observation sheets, student discussion sheets, and rubrics which were used to assess student achievement. Throughout this process, the quality of lecturer interactions became more effective and helped improve the overall quality of the course.

At the beginning of the second stage, when prospective students started to work in their collaborative groups, most of the group members seemed to have difficulty discussing or exchanging ideas within their groups. Regarding this condition, the model lecturer tried to provide assistance by visiting each group of students in turn. Facilitation and guidance, as well as direction from the model lecturer, led to student interactions that were more meaningful and effective. This was evidenced by the increasing number of students engaged actively in discussions within their groups. As an example, in the last part of the lesson cycle, most of the students has been actively participated in the discussion. This finding mirrors that of Kulberg (2012) who found that lesson study triggered student to open the variation of learning. Results of this research also revealed that all PSTs acquired knowledge and insight related to indicators of scientific literacy and PCK. The development of students' scientific literacy and PCK can be seen as in Table 1.

Table 1. The Mean Score of Students' Scientific literacy and PCK indicators in each Cycle of Lesson Study.

Indicators of	LS Cycle 1		LS Cycle 2		LS Cycle 3	
	Mean	SD	Mean	SD	Mean	SD
A. Scientific Literacy						
Knowledge on science concepts	54,09	24,34	58,88	21,93	80,88	17,14
Scientific competencies	55,69	15,54	62,94	15,44	78,78	18,74
B. PCK						
Orientation on science teaching	60,19	20,84	66,91	19,08	85,13	17,14
Knowledge on science teaching strategies	41,25	18,11	60,94	20,90	84,06	17,24
Knowledge on student assessment	52,25	16,29	55,69	17,66	75,56	15,53

The students' knowledge of science concepts and scientific competencies increased slightly from the first cycle of lesson study to the second and third cycles. Similar trends were also seen for the three indicators of PSTs' PCK. These positive increases in PSTs scientific literacy abilities and PCK competences was attributed to the intervention of lesson study-based action research approach, which supports the quality of student learning. Further, the development of the PSTs' scientific literacy was comparable to development of their PCK. Regarding this Mashman & Porter (2013) noted that student teachers need to have a deep understanding of material concepts as a component of effective PCK. In this current research, activities focused on analyzing basic competencies of science lesson, creating concept maps, thinking and designing learning experiences, and formulating assessment based on the science concepts and knowledge of scientific competencies were believe to have contributed to the improvement of the PSTs' PCK.

Integration of the lesson study-based teaching approach provided an avenue for PSTs to develop their scientific literacy and PCK. During lesson study cycles, the PSTs were guided by the lecturers to engage in group reflection which we believe contributed to the significant increase in their scientific literacy and PCK competencies. The effectiveness of lesson study-based action research for improving pre-service and in-service teacher competences has been noted by others (Lucenario, et al., 2016; Yangco & Espinosa, 2016). In addition, Donnelly & Hume, (2015) concluded that lecturers can play an important role in supporting students through coursework that exposes them to better pedagogical practice.

Engaging PSTs in activities, such as analyzing essential concepts, selecting teaching strategies, designing lesson plan, constructing instruments, and practicing teaching in their working groups provided opportunities for them to improve their content knowledge, and their PCK competencies. Relatedly, Calik (2015) indicated that PSTs with well designed lesson plans got more opportunities to transfer their PCK into related subject matter. Further, Karisan, et al., (2013) revealed how supporting PSTs with the knowledge base of PCK can help them develop their professional skills. Innovative intervention such as the integrating lesson study and action research approach afford lecturers the opportunity to examine their PSTs PCK development. More specifically, in the case of this current research, included development of science knowledge and

scientific competencies as part of scientific literacy. Integration of lesson study-based action research contributed to increased student knowledge and experience with teaching strategies, assessment, and their orientation toward teaching science (Nezvalova, 2011). Therefore, based on the these findings it is suggested that the PST candidates be offered more practical experiences, as well as the complementary measurement-assessment techniques, like those employed in this research, during their pre-service education.

Results of this study begins to demonstrate that the implementation of lesson study-based teaching shows promise as an effective model of teaching innovation that can improve the quality of planning, implementation, and reflection on lecturing process in science education faculty. More specifically, the quality of the lecturing process increased as the discussion-reflection at each end of the lesson study cycle (Sudrajat, 2014). Reflections on teaching and learning process as well as student learning activities became the benchmarks for improvement in the next lesson cycles. This is in line with (Coenders & Verhoef 2018; Lucenario, et al., 2016) who found that lesson study implementation was an effective way to develop student and science teacher PCK. In accordance to the advantages of lesson study, Karim (2006) indicated that implementation of lesson study in mathematics teaching had positive effects on 1) the improvement of skills of collaboration, collegiality, and communication, 3) gaining direct experience interacting with students during lecturers. The positive impacts of this research are expected to support education faculty to make lesson study a model of teaching and learning that needs to be developed by lecturers with the support of systematic and sustainable management. In other words, lesson study can be an ideal way for improving the quality of education for PSTs.

Conclusion

As a result of this study, and previous similar ones in the past, implementation of lesson study-based action research has been demonstrated to be effective in (1) improving the quality of teaching and learning process in the courses of Strategies for Teaching Biology, (2) in developing science literacy level of the PSTs, and (3) in developing the PCK indicators of PSTs as a result of the course.

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