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Enhancing Preservice Teachers' Science Self-Efficacy Beliefs and Pedagogical Content Knowledge (PCK) through Scientific Investigations

Choi, Sanghee · Lee, Young Hee†
(University of North Georgia) · (Dankook University)†

미국 초등교사교육 과정 과학교육방법론 수업(Science Methods Course)의 과학적 탐구 활동을 통한 예비교사들의 과학교수학습에 대한 자기 효능감 및 PCK 이해의 향상

최상희 · 이영희†
(북조지아대학교) · (단국대학교)†

ABSTRACT

This study was designed to enhance preservice teachers' self-efficacy beliefs and pedagogical content knowledge (PCK) through scientific investigations based on current science education reforms. To do so, a science methods course was revised to include modeling effective scientific inquiry practices as well as designing and teaching scientific investigations in the K-5 practicum classrooms (Revised Science Methods Course). This study assessed the following research questions: (1) What level of PCK do preservice teachers have before and after the completion of RSMC; (2) To what extent do participants change their self-efficacy in science teaching after completing RSMC; and (3) Is there any correlation between participants' changes in self-efficacy and the level of PCK. Participants were 76 preservice teachers enrolled in a science methods course offered at a medium-sized university in the midwestern United States. This study employed the STEBI-B survey and the PCK rubric. There result of the study indicated that there was significant increase in Personal Science Teaching Efficacy (PSTE) of the participant preservice teachers after the completion of the course. Based on the PCK rubric analysis, there was a significant increase in mean scores of the post-RSMC lesson compared to those of the pre-RSMC lesson. The correlational analysis of participants showed a positive correlation between changes in self-efficacy and the level of PCK. Thus, it may be concluded that the reform-based science methods course had a positive impact on participants' self-efficacy in science teaching through correcting misconceptions, developing higher level of PCK, and modeling scientific investigation in their practicum schools.

Key words : science self-efficacy, PCK (Pedagogical content knowledge), science methods course, inquiry, preservice teachers

I. Introduction

Current Reforms in science education call for systemic changes in K-12 science education as well as science teacher education. The National Science Education Standards (National Research Council, 1996) states, "The current reform effort requires a substantive change in how science is taught; an equally substantive

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E-mail: yhlee2014@dankook.ac.kr(Lee, Young Hee)

change is needed in professional development practices" (p.56). Recently, the NRC reemphasizes the systemic change in science education again through a Framework for K-12 Science Education (NRC, 2012), which was developed to guide the development of the Next Generation Science Standards (NGSS). The Framework states, "The framework and subsequent standards will not lead to improvements in K-12 science education unless the other components of the system – curriculum, instruction, professional development, and assessment – change…" (p.17).

To translate systemic changes in the science classroom, teachers are required to acquire different types of knowledge and skills toward innovative instructional design and new standards (American Association for the Advancement of Science, 1998; NRC, 1996). The NGSS (2013) states, "Throughout grades K-12, students should have the opportunity to carry out scientific investigations and engineering design projects related to the disciplinary core ideas" (p.9). A major goal of this reform is to develop scientific literacy through scientific investigations in student learning, allowing them to make meaningful constructions of scientific concepts.

To do this, students need to learn science through science and engineering practices, which emphasize scientific investigation on the basis of inquiry-based and problem-solving approaches. Science and engineering practice is explained by NGSS's statement, "Students at any grade level should be able to ask questions of each about the texts they read, the features of phenomena they observe, and the conclusions they draw from their models and scientific investigation (p.55)." This document also points out that the design and adaptation of science content to meet the interests, knowledge, understanding, abilities, and experiences of students is critical to promote successful science learning (NGSS, 2013).

These reforms demand that teachers develop both content knowledge as well as necessary pedagogical skills to teach science effectively. Subject matter knowledge alone is not sufficient, instead; teachers' professional knowledge of general pedagogical principles and practices is essential for effective teaching (Bransford *et al.*, 2000). Pedagogical content knowledge (PCK) is considered a critical factor to measure teachers' professional knowledge (Shulman, 1986; 1987). Researchers view PCK as a form of practical knowledge that guides teachers' understanding of science and its curricula, instructional strategies and practices (Magnusson *et al.*, 1999).

Research suggests that PCK should be an important component in science teacher education (Duggan-Hass *et al.*, 2000; Shulman, 1987). According to Park and Oliver (2008), teachers can develop a connection between content knowledge and pedagogical knowledge through the development of PCK. These teachers, therefore, become effective teachers who possess knowledge of representations of subject matter and knowledge of effective teaching practices incorporating these representations. Other researchers (Beyer & Davis, 2011; van Driel *et al.*, 1998) also suggest that PCK guides teachers to help students have better understanding of scientific ideas and concepts.

1. Self-Efficacy Beliefs and PCK

Teacher self-efficacy is the set of beliefs a teacher holds regarding his or her abilities to accomplish certain teaching tasks (Lunenburg, 2011). According to Steele (2010), teachers with a high level of self-efficacy have been shown to be more competent in their teaching and achieve at a higher academic level compared to teachers with a low self-efficacy. Therefore, teacher efficacy belief provides a useful framework for predicting teacher-teaching behavior by examining a person's belief in his or her own competency (Nespor, 1987; Riggs & Enochs, 1990). Self-efficacy beliefs are consistent with two dimensions of teacher efficacy, that of personal teaching efficacy (self-efficacy), a personal belief in their skills and abilities to be an effective teacher, and teaching efficacy (outcome expectancy), a personal belief that effective teaching will improve student learning (Bandura, 1977; Swars & Dooley, 2010).

Shulman (1986) proposed that PCK is a unique combined knowledge of content and knowledge of teachers in general pedagogy. It is a particular body of knowledge, which teachers require to perform successful teaching. Wh and Sutikno (2015) suggested that PCK contains both content knowledge of the specific discipline and knowledge of instructional strategies to teach that discipline in the classroom. Thus, PCK is specifically for professional knowledge that teachers must develop through their teacher education preparation. Students' success depends on what the teachers know about a subject and how he or she can transfer to the students what he or she knows (Kola & Sunday, 2015).

Teacher self-efficacy is regarded as a critical component of teacher education and professional development of science teachers (Hebert *et al.*, 1998). Naspor (1987) stressed that the level of confidence in teaching of teachers has a positive correlation with the level of their professional knowledge. Conceptually, PCK consisted of two dimensions: the understanding of content knowledge and the enactment of that knowledge in the classroom. Teachers with high self-efficacy demonstrated abilities to develop these two dimensions effectively (Stein & Wang, 1988). Therefore, teacher self-efficacy can be associated most closely with the successful mastery of PCK.

According to the review of literature, teacher education courses as well as college educators play a critical role in preservice teachers constructing positive beliefs in promoting reform-based science teaching (Clark & Peterson, 1986; Pajares 1992). Researchers also recognize the need to better prepare teachers to implement current science reforms by improving teaching effectiveness and developing scientific literacy (Gess-Newsome *et al.*, 2003; NRC, 2012). According to the National Science Teacher Association (2003), effective teachers develop a deep understanding and skills of PCK during their teacher education preparation and later, they design and provide appropriate science learning experiences to K-12 students. The NGSS (2013) describes this term, "skills" as "practices" to emphasize developing PCK through scientific investigations. Through these reforms, teachers are now asked to engage students in scientific practices and this, eventually, requires teachers to learn such practices for themselves. For this reason, it is necessary to bring a systemic change to science teacher education courses and also to the faculty's method of delivery.

2. Scientific Investigation and Self-efficacy Beliefs

NGSS (2013) emphasized that students should be engaged with scientific investigations by requiring both skills and knowledge that is specific to each investigation. Scientific investigation is a form of scientific inquiry that involves the formulation of a question that can be answered through an investigation. If students need to develop a greater understanding of science content when learning this way, that means, teachers must possess such knowledge and abilities to teach this way. In order to these teachers to achieve success with the use of scientific investigation, they need to increase scientific knowledge as part of their teacher education or later through professional development (NRC, 2012).

According to literature, pre-service teachers that experience learning science through scientific inquiry or investigation build their self-confidence to teach in future classrooms utilizing these practices (Duggan-Hass *et al.*, 2000; McDonnough & Matkins, 2010). This means that the experiences of teachers are an important element to change their science-teaching efficacy. Other studies found that well-designed science methods courses that are focused on scientific inquiry can successfully increase the levels of science teaching efficacy (Author, 2013; Ozdilek & Bulunuz, 2009; Palmer, 2006). These studies also found that pre-service teachers who experienced inquiry and investigation as part of their instructional framework improved their science knowledge as well as their knowledge on how to teach science.

The purpose of the study was to enhance pre-service teachers' self-efficacy beliefs and PCK through scientific investigations based on current science education reforms. A science methods course was revised to include modeling effective scientific inquiry practices as well as designing and teaching scientific practices in the K-5 practicum classrooms for the study. This study assessed the following research questions: (1) What level of PCK do pre-service teachers have before and after the completion of a revised science methods course (RSMC); (2) To what extent do these participants change their self-efficacy in science teaching after completing RSMC; and (3) Is there any correlation between participants' changes on self-efficacy and the level of PCK.

Ⅱ. Methods

1. Participants

Participants in this study were 76 preservice teachers enrolled in a science methods course offered at a medium-sized university in the Midwestern United States. All participants except one were women (75 of 76). Of the 76 preservice teachers, 68 were Caucasian and 8 were African American. Most participants (84 %) were 20-30 years of age and others (16%) were 31 to 40 years of age. The majority of the participants (91%) had completed two or three college-level science courses before this study. The science methods course, a 3-credit course, required in the Teacher Education program is usually taken during the senior year. It occurs concurrently with 140 hours of supervised school-based teaching practicum for that semester.

2. Revised Science Methods Course (RSMC)

The core framework of this revised science methods course (RSMC) was based on a constructivist idea of teaching and learning and was also a model for scientific inquiry practices for elementary preservice teachers. This course was aimed at a major goal, improving preservice teachers' pedagogical content knowledge in order for participants to enhance their confidence in teaching science. The RSMC was designed with curricula and activities to focus on core science concepts in the national and state standards. This course consisted of three phases; modeling effective scientific practices, designing two lessons, and teaching two lessons that emphasized scientific investigations in the participants' practicum classrooms.

During the process of modeling, preservice teachers were engaged in collaborative scientific investigation including formulating questions, exploring alternative solution strategies, and engaging in clinical problem-solving skills. For example, groups of participants were provided a wooden block, spring scale, a set of mass, and five different types of papers (construction paper, paper towel, aluminum foil paper, wax paper, and sand paper) and were to investigate relationships among force, motion, and friction. In this phase, participant teachers were expected to interpret the results of each investigation by using their content knowledge and the data they collected (Appendix A: part 1). After the initial investigation, groups identified and developed their own understanding of each concept and their relationships through another investigation (Appendix A: part 2). They were further challenged to make connections between these concepts and Newton's laws of motion. Then, they are asked to present their findings by using visual representations (i.e., a diagram and/or chart).

Groups finally engaged in a facilitated large group discussion followed by reviewing concepts to make sense of their experiences. Through this process, the participants deepened their understanding by correcting their misunderstandings. In this phase, an instructor facilitated a whole group discussion to review and guide them to construct the scientific content toward the investigation objective. Next, groups worked to apply the science concepts to a real world situation – control the speed of motion by strengthening or lessening the force of friction (Appendix A: part 3). After modeling scientific practices, the preservice teachers were asked to design and teach two science lessons that included inquiry-based scientific investigations for their K-5 practicum classrooms.

3. Data Collection & Analysis

The study employed one-group, pretest-posttest design and used a mixed-methods design involving both quantitative and qualitative research methodologies (Gall *et al.*, 2003; Merriam, 1998). The instrument used for this study was the Science Teaching Efficacy Belief Instrument Form B (STEBI-B; Enochs & Riggs, 1990) for use with preservice elementary teachers. The STEBI-

B consists of 23 Likert-type items that measures two subscales, the 13-item Personal Science Teaching Efficacy (PSTE) and the 10-item Science Teaching Outcome Expectancy (STOE). The reliability estimate for this instrument, using Cronbach alpha coefficient, was .87 and .69 for the subscale (Cantrell *et al.*, 2000; Enochs & Riggs, 1990). The instrument was administered to all participants at the beginning and end of the RSMC.

Teachers' PCK was evaluated through the PRIME PCK rubric (Gardner & Gess-Newsome, 2011). This rubric was designed for measuring content knowledge, pedagogical knowledge, and contextual knowledge within PCK. The PCK Content Knowledge (PCK-CK) consisted of four components including accuracy of content knowledge, connections within and between topics, and the nature of science fluency with multiple modes of representation or examples of a topic. The possible score is 12 points. The PCK Pedagogical Knowledge (PCK-PK) contains three components, rational linking teaching strategies to student learning, strategies for eliciting student prior understandings, and strategies to promote student examination of their own thinking. The possible score is 9 points. Lastly, the PCK Contextual Knowledge (PCK-CxK) includes understanding student variations, student prior concepts, and the impact of instructional decisions. The possible score is 3 points.

Participants' interviews, written reflections (Appendix B), and videotapes of their classroom teaching practices were collected to provide evidence for the PCK. Two videotapes for each participant's classroom teaching were collected at the beginning and end of the RSMC. Interviews and written reflections were collected one time at the end of the RSMC. The videotapes were further excerpted to examine "what the students do and what the teacher does." A set of these data was scored based on the PRIME PCK rubric (Appendix C). The possible PCK score was 24 based on all of the categories. Scores in the range of 0 to 7 are considered as a low level of PCK, scores in mid range of 8 to 16 are considered as a medium level of PCK, and scores in the range of 17 to 24 are considered a high level of PCK (Gardner & Gess-Newsome, 2011). For the rubric analysis of the PCK, triangulation of three evaluators was adopted and its inter-rater reliability was 0.89 ($p<.01$). The STEBI-B data was analyzed using SPSS (version PASW 18) to conduct a comparison of means between the pretest and posttest employing a two-tailed dependent *t*-test for paired samples. To measure the correlations between the self-efficacy and level of PCK, a Canonical Correlation was calculated. This analysis allows investigating between variables (Afifi *et al.*, 2011).

III. Results & Discussion

1. Changes in Self-Efficacy

Mean scores, standard deviations, and a dependent, two-tailed t-test for paired samples were applied to the STEBI-B subscales (Table 1). Table 1 shows a significant difference between the mean scores of the pretest and posttest. The participant preservice teachers had significant increases in their science teaching efficacy mean scores ($P<.05$) which indicated significant improvement in their science teaching efficacy (PTSE) after taking the revised science methods course (RSMC). Based on the *t*-test results, the preservice teachers increased their efficacy especially in teaching science content and science experiments according to the following items: 5 (I know the steps necessary to teach science concepts effectively); 6 (I will not be very effective in

Table 1. *T*-test (two-tailed) results for self-efficacy and outcome expectancy (N=76)

	Group	Mean	SD	*t*	*p*
Teaching efficacy (PTSE)	Pre	33.66	2.38	3.259	.003*
	Post	45.84	2.97		
Outcome expectancy (STOE)	Pre	28.31	2.99	1.445	.159
	Post	30.34	7.84		

*Significant $p<0.05$

monitoring science experiments); and 12 (I understand science concepts well enough to be effective in teaching elementary science) (Table 2).

On the other hand, the preservice teachers did not have significant changes in their teaching outcome expectancy (STOE) mean scores. Thus, their beliefs that students will learn as a result of their teaching did not change during the course. Based on the individual items

Table 2. *T*-test (two-tailed) results by each item (N=76)

Sub-category	Statement	Group	Mean	SD	*t*	*p*
Teaching-efficacy	1. Teacher effort	Pre	3.45	.76	2.879	.002*
		Post	4.25	.71		
	2. Better ways	Pre	4.58	.55	4.822	.000*
		Post	4.83	.71		
	3. Cannot teach well	Pre	2.70	.89	.812	.000*
		Post	3.75	.83		
	4. Effective teaching	Pre	4.45	.50	.197	.257
		Post	4.37	.69		
	5. Content teaching	Pre	2.83	.66	3.908	.000*
		Post	4.37	.93		
	6. Effective labs	Pre	2.33	.73	2.350	.041*
		Post	4.25	.75		
	7. Ineffective-low scores	Pre	3.70	.64	3.401	.137
		Post	3.50	. 84		
	8. Ineffective teacher	Pre	4.29	.54	3.788	.001*
		Post	4.16	.64		
	9. Teaching skill	Pre	2.57	.54	.849	.007*
		Post	4.33	.58		
	10. Blame teacher	Pre	2.68	.86	1.272	.006*
		Post	3.25	.96		
	11. Extra attention	Pre	2.75	.83	2.616	.021*
		Post	3.83	.83		
	12. Content knowledge	Pre	1.96	.62	2.875	.007*
		Post	2.46	.59		
	13. Effort-scores	Pre	4.12	.88	1.729	.094
		Post	3.54	.83		
Outcome expectancy	14. Teacher-scores	Pre	3.58	.82	2.715	.014*
		Post	4.04	.66		
	15. Effective on grade	Pre	2.25	.76	3.688	.001*
		Post	2.84	.62		
	16. Parent involvement	Pre	2.34	.65	.205	.503
		Post	2.37	.54		
	17. Difficult teaching lab	Pre	3.37	.75	1.245	.045*
		Post	4.62	.83		
	18. Answer	Pre	3.54	.84	2.335	.026*
		Post	4.00	.61		
	19. Skills	Pre	2.71	.92	1.484	.008*
		Post	4.06	1.04		
	20. No evaluation	Pre	3.37	7.22	1.010	.320
		Post	4.65	1.03		
	21. No help concept	Pre	3.68	.81	.190	.018*
		Post	3.71	.75		
	22. Welcome question	Pre	1.75	.75	2.279	.030*
		Post	4.79	.71		
	23. No way helping	Pre	3.28	.77	3.749	.007*
		Post	4.00	.84		

*Significant $p<0.05$

in STOE analysis, it is interesting to note that the participants acknowledged that teacher effectiveness was directly related to students' science achievement. However, they reported that they struggled in handling students' science questions and did not know how to encourage students' interests in science according to the following items: 15 (Students' achievement in science is directly related to their teacher's effectiveness in science teaching); 22 (When teaching science, I will usually welcome student questions); and 23 (I do not know what to do to turn students on to science) (Table 2).

2. Changes in Pedagogical Content Knowledge (PCK)

The topics which participants taught for pre and post RSMC lessons included a physical science domain (matter, changes, force and motion, magnets), a life science domain (animal and plant life cycles and cells, classifications), and an earth science domain (water cycle, weather, moon phases). All chosen topics were aligned with the national and state curriculum standards for each grade level.

Based on the analysis of participants' PCK scores (Table 3), there was a significant increase the mean scores for the post-RSMC lesson compared to those of the pre-RSMC lesson ($p<.05$). The range of scores was 3.4 to 21 and its mean score was 18.25 for the post-RSMC lesson. For the pre-RSMC lesson, the range of scores for PCK-Total was 0 to 9 and its mean score was 6.74. Looking at the mean scores in sub-categories, not only did participants' PCK-Total improve but each sub-categories such as PCK- content knowledge (CK), pedagogical knowledge (PK), and contextual knowledge (CxK) also improved after taking the course ($p<.05$). PCK-CK was 7.65 out of 12, PCK-CK was 6.98 out of 9, and PCK-CxK was 2.1 out of 3 for the post-RSMC lesson and PCK-CK was 2.15 out of 12, PCK-CK was 1.36 out of 9, and PCK-CxK was 0 out of 3 for the pre-RSMC lesson.

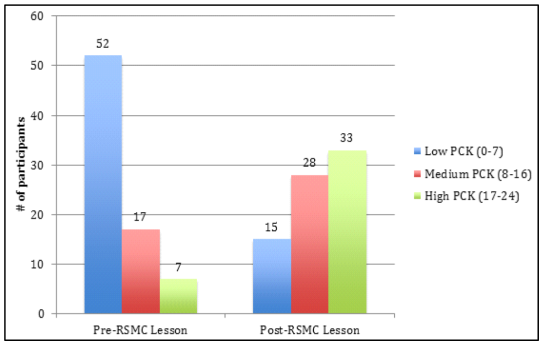

Fig. 1. Participants' level of PCK
*Significant $p<0.05$

According to the level of participants' PCK (Fig. 1), participants significantly increased the level of PCK after the completion of the course. Forty-three percent (33) of the participants scored a high PCK, 36.8% (28) participants marked medium PCK, and 15.8% (15) participants exhibited low PCK for the post-RSMC lesson. On the other hand, 9.5% (7) participants scored high PCK, 22.6% (17) participants marked medium PCK, and 67.9% (52) participants exhibited low PCK for the pre-RSMC lesson. Based on the results of PCK analysis, participants gained significant content knowledge and developed effective teaching strategies to teach science. They also constructed a deeper understanding of their students' prior concepts, which is essential for their successful learning experiences.

3. Correlations: Self-Efficacy and Pedagogical Content Knowledge (PCK)

Table 4 shows the results of the correlational analysis

Table 3. Mean scores of participants' PCK (N=76)

	PCK-total				PCK-CK				PCK-PK				PCK-CxK			
Categories	Pre	Post	*t*	*p*	Pre	Post	*t*	*p*	Pre	Post	*t*	*p*	Pre	Post	*t*	*p*
Possible score	24				12.00				9.00				3.00			
Mean	6.74	18.25	2.67	.009*	2.15	7.65	3.19	.017*	1.36	6.98	2.17	.008*	0	2.10	2.23	.014*

*Significant $p<0.05$

Table 4. Correlation between self-efficacy and PCK

Categories	PCK-Total	PCK-CK	PCK-PK	PCK-CxK
PTSE	.704*	.629*	.728*	.616
STOE	.623*	.615*	.632*	.622*

*Significant $p<0.05$

of participants' changes in self-efficacy and the level of PCK. The participants exhibited a strong positive correlation between PCK-Total score and the Personal Science Teaching Efficacy (PSTE) and a moderate positive correlation with the Science Teaching Outcome Expectancy (STOE) ($p<.05$). By sub-categories, there were moderate positive correlations between PTSE and PCK-CK and PTSE and PCK-PK. There were also moderate positive correlations between STOE and PCK-CK and PCK-PK and PCK-CxK.

Based on the results of STEBI-B and Table 4, the participants increased their science teaching self-efficacy by gaining confidence in their content knowledge and pedagogical knowledge throughout the course. Interestingly, the PCK Contextual knowledge (PCK-CxK) showed a positive correlation with Science Teaching Outcome Expectancy (STOE). Since the PCK-CxK explains one's understanding of leaners and learning, this understanding is likely to change one's belief about their teaching will improve students' learning.

IV. Conclusions

This study was designed to enhance preservice teachers' self-efficacy beliefs and PCK through scientific investigations based on current science education reforms. A revised science methods course (RSMC) was developed for this study. The results of the study indicated that there was significant increase in PTSE for the participant preservice teachers after the completion of the course. However, there was no significant change in STOE. Based on the analysis of PCK rubric, there was a significant increase in mean scores of the post-RSMC lesson compared to those of the pre-RSMC lesson. In the pre-RSMC lesson, more than 50% of participants exhibited a low level of PCK, but in the post-RSMC lesson, the majority of participants (84%) demonstrated medium to high levels of PCK.

Studies suggested that prior science learning experiences is strongly associated with PTSE scores. They reported that preservice elementary teachers with positive science learning experiences demonstrated higher scores in PTSE (Bleicher, 2004; Mulholland *et al*., 2004). According to Bandura (1977), self-efficacy is promoted by performance accomplishment, which is defined as a personal successful experience of a specific task of learning. Tosun (2000) noted that negative science learning experiences induced a dislike toward science and its teaching. Other important factors that related to higher efficacy in science teaching included science content knowledge (Swars & Dooley, 2010), number of science courses taken, and extra science activities (i.e., science fairs, science club, etc.) in high school (Bleicher, 2004; Cantrell *et al*., 2003).

According to recent literature, a science methods course, only when it is well structured, can be successful in improving science teaching efficacy of preservice elementary teachers. Instructional strategies, in which these studies employed, included inquiry approach (Christol & Adams, 2006; Palmer, 2001; Wee *et al*., 2004), project-based learning (Yoon *et al*., 2006) and field-based learning (Swars & Dooley, 2010). Specifically, McDonnough and Matkins (2010) found that scientific investigation also enhanced preservice teachers confidence in teaching. They suggested that scientific inquiry and its investigation increased preservice teachers' self-efficacy by helping them to develop knowledge in science and pedagogical skills in science instruction.

Bandura (1977) stated that self-efficacy indicates the link between teachers' PCK and their perceptions of their own science teaching ability. Carrier (2009) further suggested that teachers' self-efficacy can be improved with development of PCK and the PCK can be improved through teaching experiences. Another researcher added that preservice teachers develop their PCK through teacher education courses (Hebert *et al*., 1998). However, Appleton (2003) claimed that reformed science methods courses do not always lead to the success of improving preservice teachers' PCK. The revision must emphasize student misconceptions and constructivist views of learning in order to bring successful changes in self-efficacy and PCK.

The results of a correlational analysis for this study indicated the participants increased their science teaching self-efficacy by improving their content knowledge (PCK-CK), pedagogical knowledge (PCK-PK), and understanding of students (PCK-CxK) through the course. These participants exhibited a strong positive correlation between self-efficacy and PCK-Total in science teaching as well as its sub-categories. According to Stein and Wang (1988), teacher self-efficacy is an important element to connect content knowledge and pedagogical skills of teachers in order to master PCK successfully. Thus, it may be concluded that the reform-based science methods course had a positive impact on participants' self-efficacy in science teaching. This resulted in participants building confidence in their own science teaching through correcting misconceptions, developing higher level of PCK, and modeling inquiry instruction in their practicum schools through scientific investigations.

Consideration regarding no changes in the STOE scale scores in this study and other studies may relate to the preservice teachers' degree of successful science teaching experiences. Mulholland *et al.* (2004) suggested that preservice teachers' inexperience in teaching may lead to their low science teaching outcome expectancy (STOE). As a result they do not trust that their effectiveness will make a difference in student learning. Thus, researchers emphasize the importance of early field-experiences for preservice teachers to provide opportunities for teaching experiences (Cantrell *et al.*, 2003; McDonnough & Matkins, 2010; Swars & Dooley, 2010). Additionally, other researchers reported that there are high possibilities that preservice teachers do not have enough opportunities to observe effective science instruction and practice their science teaching in their field placement classrooms due to the neglect of science instruction by elementary schools as well as teachers (Banilower *et al*., 2006; Davis *et al*., 2006). Therefore, it is also recommended that the field-experiences must provide adequate opportunities of quality teaching observations and teaching practices in science.

The findings in this study suggest that teacher preparation programs should make some changes in their curriculum and instruction in order to increase teaching efficacy and further higher teaching effectiveness. It is true that higher efficacy in science teaching has a positive impact on preservice teachers' development of their pedagogical knowledge and vice versa. This will eventually impact their teaching effectiveness. The findings of this study provide teacher educators and teacher preparation programs important information to better prepare future elementary teachers.

국문요약

본 연구는 현 과학교육의 개혁 운동에 기초하여 예비 교사들의 자기 효능감과 교과교육지식(PCK) 이해의 향상을 위하여 과학적 탐구를 실행하였다. 이를 위하여 과학교육 방법론 수업(Science Method Course)은 초등학교 교실에서 실행할 수 있는 효과적인 과학 탐구 모델링 수업과 과학적 실천 교수학습을 포함하도록 수정하였다(RSMC). 본 연구에서는 다음과 같은 연구 문제를 조사하였다: (1) 수정된 과학교육 방법론 수업(RSMC)의 처치 전후 예비 교사들의 PCK 정도는 어떠한가?: (2) RSMC 이수 후 과학 교수학습에서 예비교사들의 자기 효능감의 정도는 어떻게 변화하였는가?: (3) 예비교사들의 자기 효능감과 PCK 수준의 변화는 어떤 상관관계가 있는가? 연구에 참여한 예비교사들은 미국 중부의 중간정도 규모의 대학의 교사교육 과정에서 제공하는 과학교육 방법론 수업에 등록한 76명이며, 분석을 위해서 STEBI-B 설문지와 PCK 평가지를 이용하였다. 본 연구의 결과로는 예비교사들이 RSMC 이수 후 개인적 과학교수 효능감(PSTE: Personal Science Teaching Efficacy)이 확실히 향상된 결과를 볼 수 있었다. 또한 PCK 평가지에 근거하면, RSMC 전과 후의 PCK 수준은 평균값이 현저히 상승하였으며, 예비 교사들의 자기 효능감과 PCK 수준의 변화 사이의 상관관계 분석에서는 긍정적인 상관관계를 보여주었다. 따라서 본 연구에서는 과학교육 개혁 운동에 근거하여 설계된 과학교육방법론 수업(RSMC)은 예비 교사들의 오개념의 수정, PCK

수준의 향상 증진, 그리고 현장 학교에서 탐구수업의 모델링 등을 통하여 과학교수학습에서 자기 효능감의 향상에 긍정적인 영향을 미친다고 결론 내릴 수 있다.

주제어: 자기 효능감, 교과교육지식(PCK), 과학교육 방법론, 탐구, 예비교사

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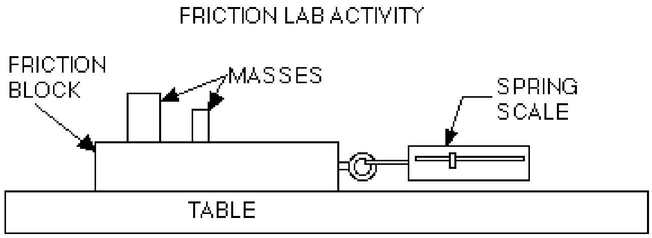
Appendix A

An Example of Scientific Investigation: Friction & Newton's Second Law

Objective: Friction is a very common (and sometimes troublesome) force. But do you know how it works? Do you know what the force of friction depends on?

Focusing Question: If you are dragging the block at a constant velocity, what is the relationship between the force you are applying and the force of friction?

Martials: wooden blocks, mass sets, spring scale, five different surfaces (construction paper, paper towel, aluminum foil paper, wax paper, and sand paper)



Procedure:
1. Attach the spring scale to the wooden block
2. Gently pull the block and read the scale in Newton.
3. You are measuring the force required to move the block. Do not pull the scale up or down at an angle; always pull it directly sideways.

Part 1. Friction and the Normal Force

Question: If you are dragging a box across the floor, and somebody jumps onto to it, will the box be harder to pull?
1. Write your prediction.
2. Investigate this by measuring the friction force between the block and the table as you add weight to the block. Try different masses (from 0.5 kg to 5.0 kg), and complete the table (see sample table below).

Trial	Mass	Force
1		
2		
3		

3. Sketch 2 graphs here. On the first, plot the Force of Friction on the vertical axis and the Mass on the horizontal axis. On the second graph, plot the Force of Friction on the vertical axis and the Normal Force (Mass * kg) on the horizontal axis (just rough sketches).
4. Examine your data and sketch. What do you conclude about the relationship between increasing mass (thus increasing Normal force) and friction?

Part 2. Friction and the Surface Type

Surface type (material, texture) certainly affects friction between two objects. To examine this, you need to look at the frictional force as you change materials. Use a constant mass (1 kg) and change the materials. Create a small table below with the different surfaces and the frictional force measured.

1. Record the items you tested and rank them from least friction to greatest friction.
2. Based on the investigation of friction, what two things does the force of friction depend on? Be specific about HOW it affects friction (increases, decreases, etc.).
3. Write a conclusion between the normal force and the force of friction related to the Newton's second law

Part 3. Extension

Friction can be described as the resistance to motion created by two objects moving against each other. This force can be either helpful or a hindrance. In order for a car to turn, stop, and even begin moving a certain amount of friction is helpful. Too much friction could stop a car from ever moving at all. Without friction, running, walking, picking up a toothbrush and even standing would be a difficult chore. Most machine inventors try to reduce the friction on the working parts to increase efficiency. For example, car engines need clean lubricant to reduce friction to help moving parts work efficiently. If the lubricant becomes too dirty, the dirt particles will provide too much friction inside the moving parts and may cause the engine to overheat and shut down. Another example to illustrate the decrease in efficiency due to resistance might be to compare two pairs of scissors. One may be rusty and hard to move while the other is clean, new, and easy to maneuver. The rusty scissors illustrate how too much friction can cause a compound machine like scissors to become less efficient.

1. Go to the school parking lot and look at the vehicles. Discuss the different shapes of cars, the possible problems or advantages of certain tire types, sizes, and treads, and any other aspects of the vehicles that may relate to friction and/or efficiency.
2. Put a large, heavy box on the floor in the room. Try to list ways to move it in the easiest way possible.

Appendix B

PCK Reflection

1. How did you feel the lesson went? What went well? What did not go well?
2. As you reflect on your lesson, how did it actually unfold compared to what you anticipated happening as you planned? What caused this change (e.g., students knew more during the pre-assessment than expected, a student's behavior altered the way I introduced the lesson, etc.)?
3. Did all students understand the lesson (provide evidence to support)? Do some students need more practice (provide evidence to support)?
4. How will you use your students' performance today to plan the next step of their learning?
5. If you were to teach this lesson again to these students, what changes would you make?