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Contributions of Inquiry-Based Hands-on Physics Activities to Turkish Elementary Science Teachers' Subject Matter Knowledge

Research Article

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ABSTRACT

This study aimed at investigation of the development of elementary science teachers' subject matter knowledge through some selected hands-on activities based on inquiry-based instruction. 58 voluntary elementary science teachers participated in the study with non-random convenience sampling. The elementary science teachers in the study carried out 15 inquiry-based hands-on physics activities. To assess Subject-Matter Knowledge (SMK), three instruments about some selected physics content (mechanics, optics, pressure, electricity, and heat) and science process skills were utilized as pretests and posttests: Traditional Problems Test (TPT), Context-Based Problems Test (CBPT), and Science Process Skills Test (SPST). Scores, particularly on the TPT and CBPT, indicated unsatisfactory levels of SMK in physics. Furthermore, performances were better on the TPT rather than the CBPT. In consequence, the inquiry-based hands-on physics activities were observed to help the elementary science teachers improve their SMK especially in terms of the CBPT scores. Finally, the SPST scores failed to reflect the progress in science process skills probably due to fatigue of testing. In sum, engagement in inquiry-based hands on physics activities seems to help the elementary science teachers develop especially their substantive knowledge.

Keywords:
Inquiry-based instruction; hands-on activities; elementary science teachers; subject matter knowledge; science process skills

Introduction

Teaching science is more than transferring knowledge from someone who knows it to someone who does not (Zhang, 2016). Such a transfer may be likely for factual knowledge. However, transferring the

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understanding of and the ability to use knowledge seems not to be possible (Gallagher, 2007). It can be therefore inferred that learning is not only knowledge acquisition. Students must also be able to understand and have the ability to use it.

In this regard, teaching gains a new perspective. Rather than transferring knowledge, it requires instructors to provide students with some facilities so that they are able to construct the desired knowledge in their mind (Scott, Asoko, & Leach, 2007; Zhang, 2016). This new perspective may raise such a question: what must such a teaching look like? In traditional teaching, there is a teacher presenting information to students in front of the class. There are students listening to the instructor, rarely asking questions, and usually working alone from their textbooks. Instead of such traditional instruction, students should be engaged in laboratory or hands-on activities as well (Gallagher, 2007). Thus, many hands-on activities are presented in textbooks. However, they are usually presented as step-by-step instructions and teachers make students carry out them traditionally (Huber, & Moore, 2001). Because students are passive in traditional lectures, conceptual science understanding cannot be promoted as desired (Hake, 1998). As Hake reported, engaging students interactively not only in hands-on but also heads-on activities prevailed against the traditional method in conceptual understanding of students.

While scientists carry out scientific activities in order to produce scientific knowledge, they construct a hypothesis, design experiments to test their hypothesis and propose explanations based on evidence derived from their work (NRC, 1996). Such processes scientists do when they do science to produce knowledge are called scientific inquiry (Anderson, 2007). However, in traditional science instruction (cookbook laboratories), students do experiments to confirm scientific knowledge (Blanchard et al., 2010). What if students do activities/experiments to discover scientific knowledge? Is it possible for students to behave like scientists? Such questions resulted in a contemporary approach in science education: inquiry-based instruction.

In inquiry-based instruction, students carry out activities in science classes similar to scientists so that they develop an understanding of scientific knowledge, desirably on their own (Blanchard et al., 2010; NRC, 1996; Trumper, 2003). Therefore, it is not surprising that there is evidence it provides meaningful learning (Kubicek, 2005; National Research Council [NRC], 2000) and develops the scientific thinking (Bianchini & Colburn, 2000). Consequently, science educators are suggested to support their students with the inquiry-based instruction (Lunetta, Hofstein, & Clough, 2007). Meanwhile, the role of the teacher is guidance rather than knowledge transmission. Inquiry-based instruction can be categorized into four levels with respect to the level of the guidance: (1) level 0 – verification, (2) level 1 – structured, (3) level 2 – guided, and (4) level 3 – open inquiry (Blanchard et al., 2010). In level 0, the instructor helps the students draw the expected conclusion by providing them with the question to be investigated and the data collection method. In a structured inquiry, the instructor again provides the students with the question to be investigated and the method for data collection; however, students draw conclusions on their own. In a guided inquiry, the students decide how to test the hypothesis of which themselves construct. In open inquiry, even the question to be investigated is raised by the students. Therefore, the students carry out almost all the stages in inquiry-based instruction. Accordingly, it can be concluded that the level of guidance is very important for implementing inquiry-based instruction. In other words, knowledge of elementary science teachers seems to be really crucial for an effective science teaching. Therefore, there is an extensive literature on what science teachers should know.

A systematic definition of teacher knowledge was presented as a model by Abell (2007). This model was modified from Grossman (1990) and Magnusson, Krajcik, and Borko (1999) (as cited in Abell, 2007). Accordingly, science teacher knowledge has three main interrelated components: Pedagogical Knowledge (PK), Science Subject Matter Knowledge (SMK), and Pedagogical Content Knowledge (PCK). PK includes the knowledge of instructional principles, classroom management, learners and learning, and educational aims. PCK includes knowledge of science instructional strategies and science assessment. Finally, SMK is consisted of substantial and syntactic knowledge. However, the components of SMK, which is in the scope of this study, seem to be expanded in the review study of Cochran and Jones (1998). Accordingly, the SMK includes content knowledge, substantive knowledge, syntactic knowledge, and beliefs about the subject matter. Science content knowledge means the facts and concepts in science. On the other hand, the substantive knowledge is first defined by Schwab (1964; as cited in Abell, 2007), and that definition seems to be slightly different in the Cochran and Jones (1998) study. The former defines the substantive knowledge as the organization of the facts, concepts, theories, and principles in science while the latter defines as the explanatory structures or paradigms in science. Further explanations about the substantive knowledge in Cochran and Jones (1998) shows their definition is consistent with the definition by Schwab (1964). Therefore, the d efinition of Schwab (1964) for the substantive knowledge is used in this paper. In addition, it is also reported that identifying the distinction between the content and substantive knowledge in science is not easy (Carlsen, 1991; as cited in Abell, 2007). The syntactic knowledge is related to the ways in which new knowledge is generated in science. Finally, the beliefs about subject matter mean learners and teachers' feelings about various aspect of the subject matter.

In elementary science teacher education programs, providing prospective elementary science teachers with undergraduate degrees in the related subject areas (e.g. physics, chemistry, and biology) is assumed to help them acquire an adequate knowledge base for teaching (Anderson & Clark, 2012; Cochran & Jones, 1998). However, misconceptions and learning difficulties elementary science teachers hold and face are reported frequently in the literature, and this situation has brought up questions about SMK of elementary science teachers for several decades not only in Turkey but also all over the world (Anderson & Clark, 2012; Aydin & Boz, 2012; Cochran & Jones, 1998). Either few or no research studies is reported in the literature pertaining to research on syntactic knowledge or epistemic knowledge, which is another component of SMK (Aydin & Boz, 2012; Anderson & Clark, 2012). Elementary science teachers are reported not only to have inadequate SMK but also inadequate PCK. Specially, Turkish elementary science teachers have been reported to experience difficulties in implementing different instructional methods and strategies (Aydin & Boz, 2012).

Purpose of the study

A project, "Amazing Science Lessons, Inquisitive Students and Popular Science (ASLISPS)" funded by the Scientific and Technological Research Council of Turkey (abbreviated as TUBITAK in Turkish) was carried out for development of elementary science teachers' subject matter knowledge (SMK). Their SMK was assessed via three instruments. First one was consisted of traditional physics problems (TPT) similar to the problems in science textbooks to assess the content knowledge, the second one was consisted of real-life physics problems or context-based physics problems (CBPT) to assess the substantive knowledge. It was assumed the CBPT would require the elementary science teachers to utilize a much more explanatory structure of physics knowledge (substantive knowledge) with respect to the TPT. In addition, both tests were developed using the same objectives obtained by means of the selected hands-on activities. The third instrument was the Science Process Skills Test (SPST) to assess the teachers' science process skills which are assumed to be related to the syntactic knowledge, another component of the SMK. As a consequence, whether elementary science teachers could show similar performances and progress on these tests was investigated in this study. As well as, the performances and progress of male and female elementary science teachers were compared. Null hypotheses which are tested in the study are as follows:

1. There is no statistically and practically significant difference between performances of the elementary science teachers on the CBPT and TPT prior to the treatment?

2. There is no statistically and practically significant interaction between the gender of the elementary science teachers and the measurement of the SMK via two partially parallel tests.

3. After the treatment, regardless of gender of the elementary science teachers, they do not make a statistically significant progress.

a. Elementary science teachers do not demonstrate a significant progress in content knowledge because of inquiry-based hands-on activities.

b. Elementary science teachers do not demonstrate a significant progress in substantive knowledge because of inquiry-based hands-on activities.

c. Elementary science teachers do not demonstrate a significant progress in science process skills because of inquiry-based hands-on activities.

4. Male and female elementary science teachers' performances on the set of TPT, CBPT, and SPST are affected similarly by inquiry-based hands-on activities.

a. Male and female elementary science teachers' performances on TPT are affected similarly by inquiry-based hands-on activities.

b. Male and female elementary science teachers' performances on CBPT are affected similarly by inquiry-based hands-on activities.

c. Male and female elementary science teachers' performances on SPST are affected similarly by inquiry-based hands-on activities.

Metdod

In this study, elementary science teachers who participated in the ASLISPS project carried out inquiry-based hands-on activities. Afterwards, whether there is significant improvement in those teachers' SMK was explored. In addition, it was explored whether male and female elementary science teachers demonstrated similar improvements. Therefore, this study is a one-group pretest-posttest experimental study (Fraenkel & Wallen, 1996). Finally, in line with the purposes of the study, the same instruments were administered to the participants prior to and after the treatment.

Population and sample

All elementary science teachers who were teaching students in Grades 5-8 in Bingöl, Elazığ and Tunceli provinces located in Eastern Anatolia region of Turkey in the 2013-2014 academic year formed the accessible population of this study. National Education Directorates in these provinces organized meetings to inform all the elementary science teachers working in these provinces about the project. The teachers who were interested in the project were asked for filling an application form to participate in the project. Among them, 58 volunteer elementary science teachers were selected to participate in the project. Therefore, the sampling technique can be claimed to be non-random convenience sampling (Fraenkel & Wallen, 1996). However, when the participants were selected, equality was tried to be ensured based on gender and the provinces. Therefore, purposive sampling is a little in question. Table 1 shows the distribution of the participants according to gender and the provinces. In addition, with respect to their ages and time of teaching experience, the sample was very heterogeneous and no related quantitative data is available.

Table 1. Distribution of the participants according to gender and the provinces

Provinces	Male	Female	Total
Bingöl	9	9	18
Elazığ	12	6	18
Tunceli	8	5	13
Not participate in the second phase of the project	5	4	9
Total	34	24	58

Instruments

The instruments delivered before and after the treatment to assess content, substantive, and syntactic knowledge are as the following.

Traditional problems test and context-based problems test: A test, which is consisted of textbook-style problems and includes the concepts associated with the hands-on activities (mechanics, optics, pressure, electricity, and heat), was developed by the authors in order to measure the content knowledge of elementary science teachers. The authors also developed another test which is consisted of real-life problems and includes the same concepts. Distribution of the items belonging to the Traditional Problems Test (TPT) with 16 items and the Context-Based Problems Test (CBPT) with 20 items according to the objectives and Bloom Taxonomy is given in Table 2. One question from each test is given in Figure 1 as well.

Table 2. Table of specification related to TPT and CBPT

Activities	Objectives	Bloom Taxonomy		
		Comprehension	Practice	Analyses
1. Potato and Pipette	Explains that gas pressure can be as strong as solid and liquid pressure.			CBPT1
2. Dance of dropper	a. Explains Pascal Principle b. Explains Buoyancy Force		TPT2, CBPT2 TPT3, CBPT3	
3. Is it thin or thick rope?	Explains solid pressure	TPT4, CBPT4	TPT1	
4. Moisture gauge	Defines evaporation as a cooling process.	TPT5	CBPT6	CBPT5
5. Do not let the snowman melt	a. States radiation as one of the heat transfer ways.	TPT6, CBPT7		
	b. Discovers that materials have got different thermal conductivity.		TPT 7, CBPT8	
6. Direction of the smoke	Explains convection	TPT6, CBPT9		
7. Coming close with fire is not dangerous!	Realize that the specific heat of water is very large.	TPT8	CBPT10	CBPT11
8. Is invisibility possible?	Explains refraction of light.	TPT10		CBPT12 CBPT13
9. Critical Angle Calculation	Explains total reflection.	TPT9, CBPT14		
10. Periscope	Explains reflection of light.	CBPT15	TPT11	
11. Electric Motor	Explains the electromagnetic force exerted on a conducting wire in a magnetic field.	TPT15		CBPT16
12. Why do electrical wires burn?	Realize that a conducting wire heats.	TPT12	CBPT17	
13. Importance of a fuse	Emphasize the importance of a fuse to use electricity safely.	TPT16, CBPT18		
14. Is there a frictional force on a smooth surface?	Explains the frictional force in terms of electrical forces.	TPT13		CBPT19

15. Transmission of sound	Explains in which medium sound is transmitted better.	TPT14	CBPT20

Science process skills test: To measure elementary science teachers' syntactic knowledge, which is another component of the SMK, the SPST which was developed by Burns, Okey & Wise (1985) and adapted to Turkish by Özkan, Aşkar & Geban (1992) was used. It includes 36 items and assesses the skills that scientists present when science processes are carried out. There are five dimensions of science process skills measured by the instrument: (1) identifying variables, (2) operationally defining, (3) stating hypothesis, (4) data and graph interpretation, (5) designing investigations. The reliability coefficients for SPST scores were calculated as .61 and .60 respectively before and after the treatment.

Treatment

In the ASLISPS project, 15 hands-on activities based on inquiry-based instruction were developed and these activities were administered at two-phases. Six activities were carried out in the first phase of the project while the rest were in the second phase of the project. The list of activities carried out in the project is available in Table 2. One of the activities is given in Appendix A. The elementary science teachers took the activities as groups of four to five people. Handouts (see Appendix B), similar to the handouts developed by Ünal (2012), were delivered to the groups for each activity so that the hands-on activities were carried out in an inquiry-oriented form. The groups were engaged in the activities by scientifically oriented questions. By means of the handouts, the groups set hypothesis, identified related variables, carried out observations, and developed explanations for their observations based on related physics concepts. Finally, they communicated and justified their explanations.

Assumptions

The main assumptions of this study are as follows:

1. Solving traditional physics problems, which are frequently encountered in textbooks and employed abundantly in the classrooms, requires elementary science teachers to use largely their content knowledge.

2. Solving context-based physics problems, which are commonly based on daily life experiences, requires elementary science teachers to use largely their substantive knowledge because a context-based physics problem may require them to use an organization of several science contents.

Data Analysis

In order to test the hypothesis of the study, a mixed between-within subjects analyses of variance (Pallant, 2007) and a doubly multivariate design of profile analyses (Tabachnick & Fidell, 2007) were conducted. As well as, SPSS statistics (Version 21) was used for conducting the analysis.

Results

Missing Data Analysis

There were 58 participants in total in the ASLISPS Project. However, 9 of those elementary science teachers could not participate in the second phase of the project. Thus, they could not take the post-tests either. In order to investigate if those lost subjects draw a pattern and create a problem for the comparison of the post-test scores, the pre-test scores of the present and absent teachers in the second phase of the project were compared. For that purpose, an independent variable in which the absent teachers were coded as 0 and the present ones were coded as 1 was formed. Pre-test scores of CBPT, TPT, and SPST were used as dependent variables. Because the sample size of the absent teachers is quite smaller, Mann-Whitney U Test, a non-parametric statistical technique, was utilized separately for each dependent variable collected prior to the treatments. The null hypotheses that there are no any significant differences between pre-test scores of the absent and present teachers were tested separately in each analysis. In the end, each hypothesis was observed not to be rejected. In other words, any significant differences between pre-test scores of the absent and present teachers on CBPT, TPT, and SPST were not observed (respectively z = -.68, *p* = .50; z = -.41, *p* = .69; z = -.17, *p* = .87). In addition, the effect sizes were estimated in each analysis as indicated in Palant (2007). All the effect sizes were too small as well. Therefore, the teachers who could not participate in the second phase of the project and could not take the post-tests can be assumed not to influence the data analyses of the study. Consequently, those nine teachers were excluded from the analysis. Thus, the data analyses were performed using the data from only the present teachers in the second phase. In addition, mean scores replaced missing pre-test scores of those teachers.

Descriptive Statistics

The descriptive statistics related to the first two null hypotheses are given in Table 3. The first hypothesis is about the elementary science teachers' performances on the CBPT and TPT. Mean scores of the elementary science teachers are 45.8 and 55.6, respectively for the CBPT and TPT. That is, teachers seem to be more comfortable with traditional physics problems.

Table 3. Descriptive statistics for male and female elementary science teachers' performances on CBPT and TPT prior to treatment

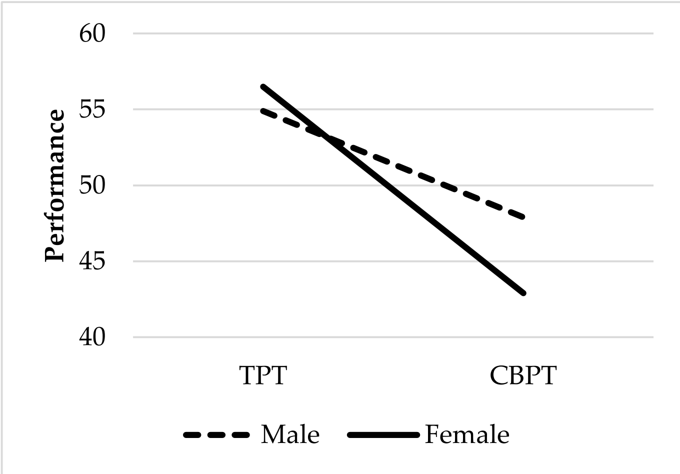
	Gender	N	Mean	SD
Performance on pre-CBPT	Females	20	42.88	15.40
	Males	29	47.87	12.32
	Total	49	45.83	13.73
Performance on pre-TPT	Females	20	56.51	9.62
	Males	29	54.90	10.21
	Total	49	55.56	9.90

The difference in performances on the CBPT and TPT seems to be different for female and male elementary science teachers. The second hypothesis deals with this situation. The difference between females and males' mean scores on the CBPT is about five points. The difference in the TPT is about two points. That is, females and males seem not to differ in performances on the TPT meanwhile they seem to differ in the CBPT in favor of males.

Inferential Statistics

In order to test the null hypotheses 1 and 2, a mixed between-within subjects analysis of variance was conducted (Pallant, 2007). The between-subjects independent variable was the gender of the elementary science teachers while the within-subjects independent variable was the measurement of the SMK via two partially parallel tests, the CBPT and TPT. Before conducting the analyses, the related assumptions were checked. The investigation of outliers did not reveal any problematic outliers. However, The Kolmogorov-Smirnov test revealed that male elementary science teachers' TPT scores are not distributed normally ($p < .05$). Thus, the skewness and kurtosis values were checked and they were observed to be very close to zero. That is, the non-normality seem not to be a problem (Tabachnick & Fidell, 2007). In addition, with no outliers, relatively equal sample sizes in groups, and two-tailed tests, the results of analyses of variance are expected to be robust enough in case the degrees of freedom for error is about 20 (Tabachnick & Fidell, 2007). Levene's Test of Equality of Error Variances revealed a non-significant result. That is, variances for males and females can be assumed to be equal. In these analyses, the most critical assumption is the Mauchly's Test of Sphericity. However, because the degrees of freedom for the within-subject independent variable (measurement of SMK) is not more than one, the sphericity is not required (Tabachnick & Fidell, 2007) and the significance value is not calculated by SPSS.

The mixed between-within subject analyses of variance were conducted after checking the assumptions. Consequently, elementary science teachers' performances on CBPT and TPT were observed to be statistically and practically to be different ($F (1, 47) = 34.07$; $p < 0.05$; partial eta-squared = .42; power = 1.00). This difference is in favor of TPT scores as aforementioned in descriptive statistics. In addition, there is practically significant interaction between the independent variables in spite of no statistically significant difference ($F (1, 47) = 3.48$; $p = .07$; partial eta-squared = .07; power = .45). In spite of the medium effect size, the interaction is statistically



non-significant because of the limited sample size (Stevens, 2009). Figure 1 shows that interaction.

Figure 1. Male and female elementary science teachers' performances on TPT and CBPT

As seen in the figure, males and females seem to be similar in performance on TPT while males seem to demonstrate higher performance on CBPT.

Null hypotheses 3 and 4 were tested by means of the doubly multivariate design of profile analysis (Tabachnick & Fidell, 2007). The between-subjects independent variable was the gender of the elementary science teachers while the within-subjects independent variable was two-level time (pre-tests and post-tests). In addition, there were three dependent variables measured prior to and after the treatment, inquiry-based hands-on activities: performances on TPT, CBPT, and SPST. The related assumptions were checked and any serious violations were not detected (Tabachnick & Fidell, 2007).

Hypotheses 3 is related to effect of the within-subjects independent variable (time). That is, if the elementary science teachers, regardless of their gender, demonstrated a significant progress because of the inquiry based hands-on activities was tested by exploring if there is a significant difference between the posttest and pretest scores. Accordingly, a statistically and practically significant difference between the posttest and pretest scores was observed for all the dependent variables ($F (3, 45) = 18.19$; Wilks' Lambda = .45; $p = .00$; partial Eta-squared= .55). Separately for scores on the TPT and CBPT, there were significant progresses ($F (1, 47) = 17.55$; $p = .00$; partial Eta-squared = .27; $F (1, 47) = 32.92$; $p = .00$; partial Eta-squared = .41). However, for score on the SPST, a significant progress could not be observed ($F (1, 47) = .11$; $p = .74$; partial Eta-squared = .00).

Test of hypotheses 4 is related to the interaction effect between the independent variables gender and time. For all the dependent variables, the multivariate test yielded statistically non-significant but practically significant results ($F (3, 45) = 2.25$; Wilks' Lambda = .87; $p = .10$; partial Eta-squared= .13). As aforementioned, the statistically non-significance while the practical significance is due to the small sample size, which is a limitation of the study (Stevens, 2009). As a result, almost a large amount of interaction effect in performances of male and female elementary science teachers because of the treatment is the case (Pallant, 2007) although it cannot be generalized to the population (Cohen, Cohen, Stephen & Leona, 2003).

The step-down analyses were conducted in order to test the hypothesis 4a, 4b, and 4c. As a result, in spite of not being able to generalize to the population, a small to medium-size interaction effect is the case for performances on TPT (F (1, 47) = 1.38; p =. 25; partial eta-squared = .03). The following figure demonstrates how the interaction is. As seen in Figure 2, male elementary science teachers benefitted more than females in terms of the performance on TPT.

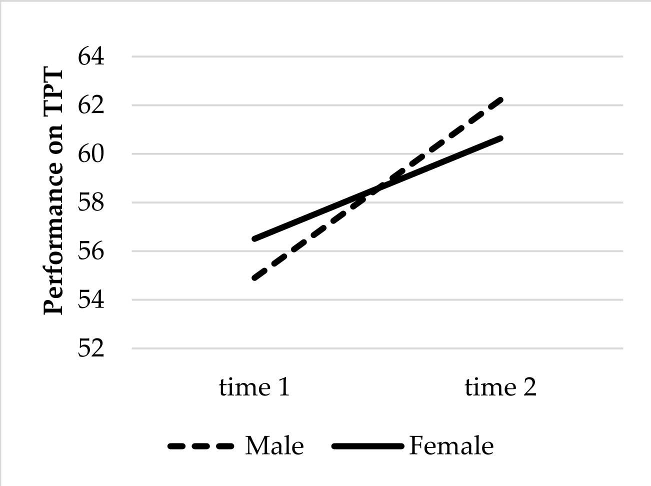


Figure 2. Male and female elementary science teachers' performances on TPT

In spite of not being able to generalize to the population, a medium size interaction effect is the case for performances on CBPT (F (1, 47) = 3.10; p = .09; partial eta-squared = .06). The following figure demonstrates how the interaction is. Prior to the treatment, males seem to be better than females in terms of the performance on CBPT. However, this gap is closed after the treatment because females benefited more from the inquiry-based hands-on activities.

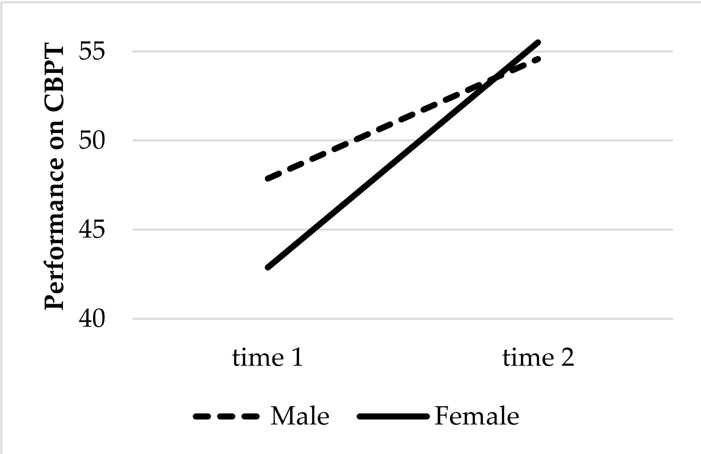


Figure 3. Male and female elementary science teachers' performances on CBPT

Again in spite of not being able to generalize to the population, a medium size interaction effect is the case for performances on SPST (F (1, 47) = 2.95; p = .09; partial eta-squared = .06). The following figure demonstrates how the interaction is. This result is very interesting. Although both male and female elementary science teachers are expected to acquire science process skills due to the inquiry-based instruction, males' performance on SPST decreases while females' performance increases.

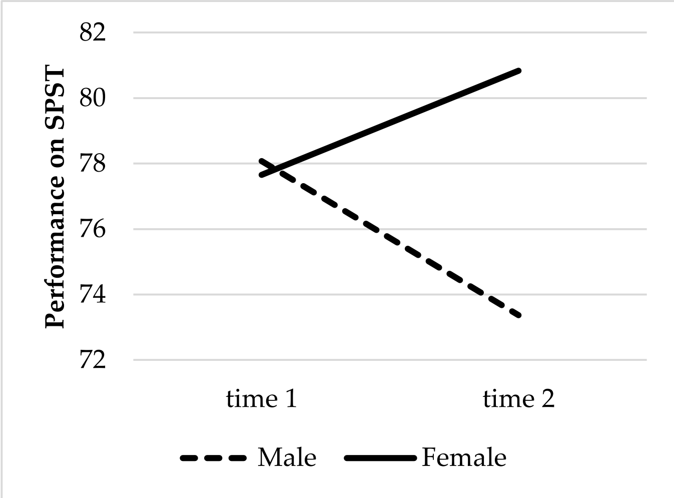


Figure 4. Male and female elementary science teachers' performances on SPST

Conclusions, Discussions, and Implications

In this study, two parallel form tests developed by the researchers based on the objectives identified according to the selected hands-on activities were used to assess elementary science teachers' subject matter knowledge. One of the tests (TPT) was prepared using traditional textbook-style physics problems while the other one (CBPT) was prepared using real-life physics problems. The major assumption was that the TPT assessed mostly content knowledge of the elementary science teachers while the CBPT assessed mostly the substantive knowledge.

Consequently, the mean pretest score of elementary science teachers on TPT revealed that they had an unsatisfactory level of content knowledge in physics. It was 55.6 over 100. A similar finding was observed when physics related subject matter knowledge of junior secondary school teachers in Hong Kong was identified using true-false items (Yip, Jung, & Mak, 1998). According to the literature, elementary science teachers face a problem of deep understanding (Cochran & Jones, 1998). Consistently, the elementary science teachers in this study demonstrated more difficulty in real-life physics problems. The mean pretest score on the CBPT was 45.8 and it was significantly smaller than the mean score on the TPT. That is, elementary science teachers seem to be more deficient in substantial knowledge rather than the content knowledge in physics topics. When gender differences were investigated, it was observed that males and females seemed to demonstrate similar performances on the TPT. Not surprisingly, performances of both males and females decline on the CBPT. However, the performance of females declines more, and thus, a gap starts to appear between the performances of males and females in favor of males. The effect size of this interaction was medium.

Related to the effect of inquiry-based instruction, the use of inquiry-based instruction usually results in positive influences on conceptual understanding or achievement, science process skills, and attitudes towards science (Abraham, 1998; NRC, 2000; Treagust, 2007). However, observing better result in content achievement is not as easy as in the attitude towards science. There are a group of studies reporting no better or moderate result of inquiry-based instruction in science education (Abraham, 1998; NRC, 2000). At this point, it should be emphasized that there was no control group in this study. Thus, the effect of inquiry-based instruction with respect to another teaching method on subject matter knowledge is not reported in this study. Instead, if or not male and female elementary science teachers benefitted in the same way from the ASLISPS project was investigated.

First of all, a statistically and practically significant difference between the posttest and pretest scores was observed for all the dependent variables. Separately for scores on the TPT and CBPT, there was significant progress. However, for the score on the SPST, a significant progress could not be observed. When if or not male and female elementary science teachers were influenced similarly was investigated, both males and females demonstrated progress on TPT, however, males showed more progress with respect to females. The effect size of that interaction was small-to-medium. On CBPT, prior to the treatment, there was a gap between performances of males and females in favor of males. However, following the implementation of inquiry-based hands-on activities, females showed more progress and the gap disappeared. There was a medium effect size interaction. In consequence, the inquiry-based hands-on activities seem to help elementary science teachers get progress in their subject matter knowledge. Particularly, the progress in the performance on CBPT is more pleasing because students are reported to have more difficulty in explaining real-life problems (Cochran & Jones, 1998). As well as, when students are provided with actual experiences including the scientific processes, it may help them construct the related science knowledge. In this way, they may connect the abstract science content to its practical meanings in real-life problems (Zhang, 2016). Such a relationship between constructivism and inquiry science teaching may account for why inquiry-based hands-on activities closed the gap between males and females on the CBPT, consisted of real-life physics problems.

With respect to SPST for assessing syntactic knowledge, male and female teachers demonstrated similar performances prior to the treatment. Erkol and Ugulu (2014) assessed 121 Turkish preservice biology teachers' science process skills using the same instrument. In their analyses, they found no significant difference between the science process skills of males and females. That is, this finding is consistent with the finding of this study. However, following the inquiry-based hands-on activities, a gap appeared between the performances of females and males in favor of females. The interaction demonstrated a medium effect size. It is complicated to account for such an unexpected finding. However, SPST was delivered after TPT and CBPT were administered. Therefore, male elementary science teachers may have become fatigued and filled the SPST arbitrarily. The authors explored if this is the case by checking the alpha reliability coefficients separately for males and females' SPST posttest scores. The alpha coefficients were calculated as .54 and .67, respectively for males and females. That is, the SPST posttest scores seem to reflect females' science process skills more accurately than the males'. As a result, the gap in SPST posttest scores in favor of females may be due to the fatigue of testing, and males' science process skills may have been promoted like females'.

Consequently, although there was no control group in this experimental study, inquiry-based hands-on physics activities were observed to help elementary science teachers develop their SMK. The elementary science teachers were observed to get progress especially in terms of real-life problems with respect to the traditional textbook style physics problems. This study supports the literature emphasizing the importance of providing elementary science teachers with inquiry-based hands-on activities (Huber, & Moore, 2001; Welch, Klopfer & Aikenhead, 1981). Also, more powerful research studies with control groups are suggested in the future. However, the use of instruments consisting of real-life problems is strongly recommended because they are expected to assess especially the substantial knowledge. Finally, males and females were observed to benefit in different ways from the inquiry-based instruction. Therefore, researchers are suggested to conduct quantitative and qualitative research studies to clarify the factors beyond such gender differences.

Conflict of Interest

No potential conflict of interest was reported by the authors.

Appendix A: A hands-on activity used in the study

Activity number: 2

Date of Activity (day/month/year): 12/09/2013

Name of Activity: Dance of Dropper

The aim of Activity: To help science teachers use hands-on activities by means of inquiry-based learning.

Duration of the Activity: 45 minutes

Materials: A water filled the 1.5-liter plastic bottle and a medicine dropper made of glass.

Number of Participants: 50 middle school science teachers

Implementation of Activity:

The instructor asks the elementary science teachers to create groups of 3-5 members. Later, each group is provided with the materials. The instructor places the dropper in the water-filled bottle and secures the top. Afterward, the instructor asks the elementary science teachers what will happen to the dropper if the closed water-filled bottle is squeezed and released. After the elementary science teachers discuss within the groups, each group constructs their hypothesis. Following the construction of hypothesis, the instructor allows the groups to carry out the experiment; and thus, to make observations. Using the data the groups collect, the hypothesis is tested; they are supported or rejected. Finally, each group shares its result with all the groups and conclusions are discussed in the class.

Appendix B: Handouts delivered to groups

HANDOUT

Group Number:………………………………………………………………………

Name of Activity:……………………………………………………………………

Set hypothesis

……
……
……

Identify the variables

Independent variable/s: ……………………………………………………………………

Dependent variable/s: ……………………………………………………………………..

Constant variable/s: ………………………………………………………………………….

If any, uncontrollable variable/s: ………………………………………………………….

What is your observation?

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……
……
……

Which physics concepts are related to this activity?

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How do you interpret your observation?

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Appendix C: A question from the context-based problems test

In the news on television, information on how to rescue people after an earthquake is being presented. An expert states that an alive person who is stuck in a devastated building should hit a small piece of broken wall or stone on the devastated building walls instead of screaming. Why may hit a small piece of stone on the walls instead of screaming be more effective in such a case?

The Partially Parallel-Form Question from the Traditional Questions Test

I. Gases

II. Solids

III. Liquids

IV. Free Space

Rank the mediums given above in the order of highest to lowest sound conductivity.

A) III > II > I > IV

B) III > I > II > IV

C) II > I > III > IV

D) II > III > I > IV

E) II > IV > I > III

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