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Promoting Preservice Teachers' Attitudes toward Socioscientific Issues

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Abstract

In this study, we aimed to improve preservice teachers' attitudes toward socioscientific issues through socioscientific issue course. Moreover, we investigated whether this course influences preservice teachers studying in a science education and non-science education in a similar way. For this purpose, a semester-long socioscientific issues course was designed and implemented. Data were collected from a science education group (preservice science teachers) and a non-science education group (preservice social-science teachers). In order to evaluate participants' attitudes towards socioscientific issues, Attitudes towards Socioscientific Issues Scale was utilized before and after the course. This scale evaluates attitudes under three themes: liking of socioscientific issues, interest and usefulness of socioscientific issues, and anxiety towards socioscientific issues. The result revealed that socioscientific issues course provided similar gains for both preservice science teachers and preservice social-science teachers on interest and usefulness of socioscientific issues, liking of socioscientific issues, and anxiety towards socioscientific issues. That is both groups derived a similar benefit from the socioscientific issues course. Specifically, socioscientific issues course contributed to preservice teachers' interest and usefulness of socioscientific issues, and liking of socioscientific issues positively. On the other hand, their anxiety scores did not change significantly after the course. These findings imply that, regardless of majors, socioscientific issues course has potential to favor preservice teachers' attitudes toward socioscientific issues.

Introduction

"The world today is both an exciting and difficult place in which to live" (Massialas, Sprague, & Hurst, 1975, p.5). It raises many challenges for citizens. Energy crisis, consumer choices, health decisions, environmental concerns are some of them on which people have to take responsibility and make decisions. Deboer (2011) underscores that "As citizens of the world, there are science-based issues that affect us all, and understanding the science that underlies those issues is critical for effective global citizenship" (p. 568). These issues will be prominent in future regardless of citizens' readiness to deal with them (Sadler, 2004). These challenges are termed as socioscientific issues (SSI) because they have both social and scientific aspects as well as technology (Sadler, 2004). SSI are "complex, open-ended, often contentious dilemmas, with no definitive answers" (Sadler, 2004, p. 514). Specific examples of SSI include nuclear power plants, global warming, genetically modified food, abortion, stem cell, cloning, vaccination and experimenting on animals. Citizens learn about these issues through different mass media (e.g. news, the internet, and TV) and they often participate in public discourse to reach a decision about them. The research on socioscientific issues suggests that SSI has multiple perspectives including science, technology, economy, politics, religion, health which makes it debatable (Sadler, Barab, & Scott, 2007). The ability to discuss and make informed decisions about socioscientific issues are among the essential characteristics of science literacy. Science literacy has become a goal of science education worldwide with the aim of preparing people for rapid developments in science and technology. There is no consensus on the definition of science literacy (Roberts, 2007). Roberts synthesized the views for scientific literacy under two visions. The vision I of scientific literacy refers to an understanding of scientific concepts, principles, and processes within a determined science domain. Vision II, on the other hand, takes into account science-related issues which students face as citizens in everyday life. It gives importance to the knowledge and skills students should have to negotiate these issues and participate in decision-making process. A recent view of scientific literacy also supports Vision II. The Programme for International Student Assessment (PISA) is defined scientific literacy as "the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen. A scientifically literate person is willing to engage in reasoned discourse about science and technology" (OECD, 2015, p. 20). Scientifically literate individuals are expected to analyze and evaluate data, claims, and arguments and reach appropriate scientific conclusions (OECD, 2015). These abilities are basics of high-quality socioscientific argumentation and socioscientific decision-making process.

SSI are suitable contexts to engage students in discussions of science-related social issues. These issues have been a part of school curricula since the negotiation of these issues are accepted as an essential characteristic of citizens in modern democratic societies. There is substantial effort to include SSI in lessons to improve science content knowledge, nature of science views, argumentation skills, or critical thinking skills. Scholarly papers emphasize the teaching of SSI as one of the goals of science education for educating scientifically literate citizens (Hofstein, Eilks, & Bybee, 2011; Lee, Chang, Choi, Kim, & Zeidler, 2012; Sadler, et al, 2007; Zeidler, Sadler, Simmons, & Howes, 2005). However, SSI has been implemented not only in science education but also in many different disciplines.

In this study, we focused on preservice science and social science teachers' attitudes toward SSI because these two disciplines represent the science and social aspects of SSI. Moreover, they are all citizens of the society and they all should be responsible members regardless of the major. As citizens, they need to know about local, national, and global SSI and have the necessary skills for negotiation and decision-making. For those reasons, their attitudes toward SSI become important. In a general sense, attitude is defined as "a general and enduring positive or negative feeling about some person, object, or issue" (Petty, & Cacioppo, 1996, p.7). Maio and Haddock (2009) underlined that attitudes "influence how we view the world, what we think, and what we do" (p. 4). Teachers' positive attitudes toward SSI play a crucial role in deciding whether they incorporate SSI into their lessons. Teachers' willingness to engage in science-related issues may increase their students' interest in SSI. Teachers' implementation of SSI-based practices in their classrooms requires engaging with SSI beforehand. Therefore, SSI-based practices should be a part of their training in teacher education programs. Preservice teachers' (PTs) negotiation of SSI is important to improve their personal decisions making skills that every PTs need to use at some stage in their both daily life as a citizen and professional life as a teacher (Cansiz & Cansiz, 2015). When PTs are equipped with knowledge and skills about SSI during their teacher training, they transform these knowledge and skills to their student when they start teaching. As a result, their students are also engaged in SSI and have necessary knowledge and skills to make informed decisions on these issues. In light of this, we designed a course on SSI to engage preservice science teachers (PSTs) and preservice social science teachers (PSSTs) in socioscientific argumentation and decision making.

Incorporating SSI in a classroom environment is an effective way of supporting the development of students to be more informed and to be engaged citizens, which is one of the fundamental goals of science education (Sadler, 2011). SSI instructions facilitate students' learning science by using complicated and socially relevant issues as contexts (Sadler, 2011). Previous research showed that using SSI in teaching is beneficial for students to learn science content knowledge; develop interest, attitude, and motivation; understand nature of science; and use higher order thinking skills such as informal reasoning, problem-solving, scientific reasoning, argumentation, and critical thinking (Sadler, 2009). Some studies compared the effect of implementations including SSI with traditional science teaching methods. For example, students who participated in an intervention considering Science Technology and Society based curricula developed more positive attitudes towards science than others (Lee & Erdogan, 2007; Yager, Lim, & Yager, 2006). In another study with university students, Barber (2001) concluded that SSI-related course has a positive influence on students' interest in science and evaluation of the science content they learned. Thus, in a general sense, it can be concluded that including SSI in the classroom teaching results in enhancement of students' positive affective outcomes (Sadler, 2009).

SSI was integrated into the elementary social science curriculum in 2005 (Ministry of National Education [MoNE], 2005) and in the elementary science curriculum in 2013 (MoNE, 2013) in Turkey. Developing habits of mind through the use of socioscientific issues has become a goal of science education (MoNE, 2013). For this purpose, SSI -such as the use of food additives- were integrated into the curricula for students to discuss and argue about it. Elementary social science curriculum aims to build student' understanding of the relation between science, technology and society. Moreover, it intends for students to be able to participate in discussions related to personal or societal problems and to present their ideas to solve them. Therefore, both science and social science teachers should be able to teach SSI and also use them as a context for teaching the course content. However, they may not have enough knowledge and confidence to teach SSI. There is a substantial body of research investigating preservice teachers' knowledge of SSI and concerns for teaching SSI. Based on a critical review of related literature in Turkish context (Topcu, Mugaloglu, & Guven, 2014), most of the studies reported that Turkish preservice teachers have low level of knowledge about SSI and have concerns about teaching these issues (e.g. Soysal, 2012; Sürmeli & Şahin, 2012) although few reported high level of knowledge about SSI (e.g. Sönmez & Kılınç, 2012). In a study with 169 Turkish PSTs, Cebesoy and Dömez-Şahin (2013) asked participants to rate their level of knowledge about SSI. Most of the participants reported that they have a low level of knowledge (%53.8) and some even reported to have no knowledge at all (%5.0).

Similarly, Cansiz and Cansiz (2015) investigated preservice science teachers' views and knowledge about a specific SSI, nuclear power plant, which has recently been a hot topic on the agenda of Turkey. The results indicated that PSTs were knowledgeable about some aspects of nuclear energy yet they know little about some other aspects. For instance, while PSTs are aware of the economic burden of removing nuclear power plants, they know little about the amount of radiation emitted by nuclear power plants. Another line of research indicated that Turkish preservice teachers do not feel confident in teaching SSI as well (e.g. Alaçam–Akşit, 2011; Kara, 2012). The abovementioned studies point out that PTs' knowledge and concerns about SSI have an important role in teaching SSI. Therefore, their knowledge and confidence should be improved to prepare them to teach SSI in their future classroom.

Fostering PTs' positive attitudes toward SSI may help them to increase their knowledge about SSI as well as to reduce their concerns about teaching SSI. Having positive attitudes towards SSI means having interest to these issues, reading and discussing them, and being aware of that SSI does not adversely influence society (Topcu, 2010). People who like SSI and are interested in SSI are more likely to criticize and justify their decisions about SSI by using scientific reasoning, decision-making, and argumentation skills. Despite the educational researchers' growing interest in teaching and learning SSI, studies about attitude toward SSI are limited. One of these few studies was conducted by Topcu (2010): he developed and validated Attitudes towards Socioscientific Issues Scale, in the Turkish context. In the same study, Topcu compared science education majors and non-science education majors' attitudes towards SSI and found that science education majors have more positive attitudes toward SSI than non-science education majors. In another study, Cebesoy and Dönmez-Şahin (2013) examined PTs' attitudes in terms of gender and grade level. The authors found that there is no difference between PTs' attitudes toward SSI with respect to gender and grade level. These studies addressed PTs' existing attitudes toward SSI. However, there is a need for studies focusing on how to improve PTs attitudes towards SSI. Since it takes a long period of time to develop attitudes, PTs' positive attitudes toward SSI should be improved, before they become a teacher, to achieve the goals of the curricula. Promoting PTs' attitudes is possible through the courses which mainly focus on the SSI (Sadler, 2009). Thus, we aimed to design an SSI course in which students were engaged in role plays and argumentation on different SSI to present their ideas and refute others' who advocate a different point of view. We expect to enhance preservice teachers' interest, and liking of SSI and decrease their concerns about SSI by this course. Thus, the overarching research question and corresponding sub-questions guided this study are:

I. Do PSTs and PSSTs benefit from the SSI course similarly in terms of attitude toward SSI?
   i. How does SSI course affect PSTs' attitudes toward SSI?
   ii. How does SSI course affect PSSTs' attitudes toward SSI?

Method

In this study, we used "try something and systematically observe what happens" approach as emphasized by Fraenkel and Wallen (2006, p. 268). This is also known as establishing cause and effect relationship between independent and dependent variables. To do this, we manipulated the independent variable (SSI course) to observe the extent to which our dependent variable (attitudes towards SSI) is affected by it. Manipulating independent variables makes this study an experimental study which is a type of quantitative research methodology (Fraenkel & Wallen, 2006).

Sample

We analyzed a total of conveniently-available 86 preservice teachers' data. Among them, 54 were preservice science teachers and 32 were preservice social-science teachers. Although females far outnumber males among preservice science teachers (70% vs. 30%), the number of males exceed the number of females among preservice social-science teachers (39% females and 61% males). In terms of their average result of all grades achieved in teacher education program, PST (GPA = 2.51) and PSST (GPA = 2.68) were comparable to each other. The students' average age in both groups were similar and ranging from 19 to 28 with a mean of 22.28 (SD = 1.55). It was ensured that none of the participants in both groups had taken a course focusing on SSI before.

Instrument

Attitudes towards Socioscientific Issues Scale (ATSIS), developed by Topcu (2010), is a five-point Likert type scale and its response format is ranging from (1) strongly disagree to (5) strongly agree. In the development process of the scale, the author conducted exploratory factor analysis (EFA) as well as confirmatory factor analysis (CFA) with the data from two different samples of undergraduate students. The ultimate result of EFA yielded three factors named as liking of SSI (7 items), interest and usefulness of SSI (17 items), and anxiety toward SSI (6 items) with a total of 30 items. The cross-validation of ATSIS using CFA provided evidence that three-factor structure of the scale has a good model fit to the data. These factors, their description and sample item for each were given in Table 1.

Table 1. ATSIS factors, their description and sample item (Adapted from Topcu, 2010)

ATSIS Dimension	Description of the Dimension	Sample Item
Liking of SSI	The extent to which students have feeling of enjoyment of SSI or like SSI	"I like conducting research on SSI."
Interest and usefulness of SSI	The extent to which SSI arouse students' interest and the application of SSI is found useful among students	"Since SSI is related to daily life, I would like to learn more details about SSI."
Anxiety toward SSI	The extent to which students have concern and worries about SSI	"I think that social values suffer from the implementation of SSI."

In addition to EFA and CFA, Topcu (2010) administered reliability analysis to screen the internal consistency of the scale for each sub-dimension. He found Cronbach alpha coefficients of .90 for interest and usefulness of SSI, .81 for the liking of SSI and .70 for the anxiety towards SSI, suggesting high internal consistency of the data. Backed up by literature from attitude studies, based on related reliability and validity evidence, it was concluded that ATSIS is an appropriate instrument to measure undergraduate students' attitudes towards SSI.

In order to compare participants' pre-existing and post-implementation attitudes, we have used ATSIS before and after the implementation. Internal consistencies for each dimension related to pre-implementation were, based on Cronbach alphas, .77 for the liking of SSI, .85 for interest and usefulness of SSI, and .72 for anxiety towards SSI which satisfy the criterion of acceptability. Cronbach alphas obtained from post-implementation were found to be .85, .92, and .71 for the liking of SSI, interest and usefulness of SSI, and anxiety towards SSI, respectively. In other words, all dimensions of ATSIS were found to be reliable with our sample.

SSI Course Framework

For the purpose of the study, we designed a semester-long SSI course to promote PSTs' and PSSTs' attitudes towards SSI. Since PSTs and PSSTs were studying at different universities, they were taught by two different professors who have similar educational backgrounds. In order to ensure the similarity of implementations in both groups, each week before the course, they skyped to discuss the details of the activities each week before the course,. They also skyped after the course and discussed the extent to which they reach previously set goals. These after-course discussions indicated that they had similar activities to a great extent. The course lasted for 14 weeks and 2 class-hour for each week. At the beginning of the course, we assessed both group students' pre-existing attitudes using ATSIS. The completion of the classroom activities took 22 classroom-hour (11 weeks of the total time). The implementation was divided into two parts: teacher-guided classroom activities and student-directed classroom activities. Teacher guided activities did not include exemplary case of teaching SSI, instead they were about theoretical ideas about SSI. The details of these activities were discussed below. Right after the completion of the instruction, we measured participants' post-implementation attitudes by using ATSIS once more to be able to compare their pre-existing and post-implementation attitudes. And finally, we conducted required statistical analysis to find out the possible effect of the instruction on attitudes towards SSI. Table 2 summarizes the main points of the SSI course.

Table 2. Outline of the SSI course

Timing	Application	Classroom activities
Week 1	First Meeting	Introductions of course objectives, content, resources and process
Week 2	Pretests	Administration of Attitudes towards Socioscientific Issues Scale
Week 3-8	Teacher-guided classroom activities	Classroom discussions guided by instructor on different topic (Epistemology of science, science literacy, nations, what is SSI and etc.)
Week 9-13	Student-directed classroom activities	SSI related classroom activity organized and acted by preservice teachers
Week 14	Posttest	Administration of Attitudes towards Socioscientific Issues Scale

Teacher-guided Classroom Activities

In teacher-guided classroom activities, PTs engaged in a variety of activities under the guidance of the instructors. First of all, they discussed what science is and the life of some of the most influential scientists such as Leonardo da Vinci. The aim here was to develop PTs' understanding about the complex epistemology of science. Following that we let PTs focus on scientific and technological literacy and the status of Turkey regarding scientific and technological literacy. Then, instructors guided PTs to argue about science and technology in developed, developing, and underdeveloped countries, as well as the situation in Turkey. The teacher-guided classroom activities continued with science, technology, and society and the complex relationship between them. In the context of this topic, PTs watched a documentary film about how science, technology, and society influence each other and they reflected on it. More specifically the documentary focuses on how the modern world evolves under the influence of geographical factors as well as technological developments. Moreover, it includes how the wars among the nations have led and accelerated technological developments and how scientifically developed nations better take care of epidemic diseases than underdeveloped nations. Following week, students were introduced SSI for the first time. The classroom discussions were based on what SSI is, historical fundamentals of SSI, SSI elements in the curriculum, and teaching of SSI. We completed teacher-guided classroom activities by letting students to discuss if science is naturally good or bad. That is, when science is used in the good sense, it can be for people's benefit, but it can also be one of the greatest enemy of mankind when used in the wrong direction. For example, nuclear technology can be used in cancer treatment as well as nuclear bomb at the same time.

During teacher-guided classroom activities, the aim was not to provide PTs with teacher-centered instruction. On the contrary, instructors made every effort to avoid it and acted as a guide to make PTs explicitly and reflectively discuss each and every activity. Both instructors encouraged them to introduce their own ideas, defense it, listen to others' ideas, elaborate them, and challenge with counter-claims. While PTs were working on the activities, instructors followed them that they were active during discussions. In brief, during the first half of the instruction, discussion and argumentation methods were utilized mainly and students actively participated in teacher-guided classroom activities.

Student-Directed Classroom Activities

Student-directed classroom activities lasted for five weeks. Each week two groups completed their activities which were mostly based on role-playing and argumentation. By means of these activities, we anticipated achieving more than one objectives. Firstly, we aimed to stimulate PTs' imagination and creativity by role playing activities. Secondly, we engaged them in argumentation and decision-making process. Moreover, we expect them to develop social skills such as communication, being empathetic, and cooperative during problem-solving by group work. Above all, we aimed to improve their socioscientific reasoning skills such as looking at the same problem from multiple perspectives, understanding the importance of scientific information, and building arguments and counter arguments in the negotiation of socioscientific issues.

Before role-playing activities, each group chose a specific socioscientific issue that has a direct or indirect effect on both society and science. We suggested them to handle issues primarily from the city they were born, the city they live in, or at least from Turkey to facilitate their job in finding plenty of materials and first-hand evidence. In the context of this activity, students studied as a group of four to five. Members of the group acted their roles in front of the other class members and the instructor. Each group member behaved like a different stakeholder of the specific issue under investigation such as a politician, an authorized person in religious affairs, a scientist, a physician, or a local person. By providing concrete evidence to support themselves, group members presented their positions on the issue adhering to their role. Moreover, each PT struggled to refute others' arguments by using diverse evidence. During the end of the activity, a whole-class discussion took place by the question-and-answer method. In the end, each group aimed at reaching a possible solution of that SSI by evaluating each stakeholders' positions and evidence. Some of the example SSI were abortion, the death penalty, sperm banks, and euthanasia. A complete list of SSI was tabulated in Table 3. The selected SSI was quite similar in both groups as seen in Table 3.

Table 3. The list of SSI role played in both groups (sorted by application order)

Timing	SSI in Science Group	SSI in Social Science Group
Week 9	Carrier maternity Abortion	Organ transplant Abortion
Week 10	Mother's milk banks Nuclear power plants	Nuclear power plants Death penalty
Week 11	Genetically modified foods Cloning	Face transplant surgery Use of animals in experiments
Week 12	Euthanasia Alternative medicine	Captive breeding Global warming
Week 13	Organ Transplant Global warming	Sperm banks Euthanasia

In order to avoid PTs to engage in shallow discussion solely based on their intuitive assumptions and anecdotal evidence during role play, they were required to prepare a report containing concrete evidence like statistics reports, government documents, articles, and documentary notes before the activity. To create a deeper sense of reality, preservice teachers were encouraged to dress similar to whom they were acting during role play as well.

Results

The main objective of this study was to develop PTs' favorable attitudes toward socioscientific issues through socioscientific issue course. After a semester-long SSI course, we tested statistically if the course has an effect on preservice teachers' attitudes toward SSI as well as if this impact differs for PSTs and PSSTs by using mixed between-within subjects ANOVA. Further evaluation of assumptions showed that the data did not include any univariate or multivariate outliers, any serious deviation from normality, and unequal distribution of variance. The examination of descriptive data indicated that PSTs and PSSTs have similar scores on all three subscales of ATSIS (i.e. interest and usefulness of SSI, liking of SSI, anxiety toward SSI). For example, PSTs' anxiety toward SSI (M = 2.27, SD = .61) and PSSTs' anxiety toward SSI (M = 2.23, SD = .65) were quite similar before the course and they both indicated a low level of anxiety toward SSI. Other descriptive statistics are given in Table 4.

Table 4. Descriptive statistics related to PSTs' and PSSTs' ATSIS scores

	PST		PSST	
	Pretest Mean (SD)	Posttest Mean (SD)	Pretest Mean (SD)	Posttest Mean (SD)
Liking of SSI	3.74 (.50)	4.06 (.55)	3.89 (.61)	4.19 (.46)
Interest & usefulness of SSI	4.12 (.33)	4.31 (.42)	4.32 (.37)	4.43 (.40)
Anxiety towards SSI	2.27 (.61)	2.30 (.63)	2.23 (.65)	2.26 (.61)

Liking of SSI

Regarding liking of SSI, the result of mixed between-within subjects ANOVA indicated that the interaction between group and time was not statistically significant, Wilks Lambda = 1.00, F (1, 84) = .01, p = .926, partial eta squared < .001. That is, the influence of SSI course on the liking of SSI is independent of the major. The interpretation of main effect for time demonstrated that SSI course resulted in significant increase in liking of SSI (Wilks Lambda = .72, F (1, 84) = 32.37, p < .001, partial eta squared = .28). For in depth evaluation of both groups' liking of SSI scores, post-hoc comparisons were utilized. In order to reduce inflated Type I error resulting from multiple comparisons, Bonferroni adjustment was applied. PSTs' scores on liking of SSI significantly increased from pre-implementation to post implementation, F (1, 84) = 22.47, p < .001, partial eta squared = .21. Similarly, there was a statistically significant increase in PSSTs' scores on liking of SSI, F (1, 84) = 12.47, p = .001, partial eta squared = .13. Namely, both groups showed a significant increase in their liking of SSI scores after SSI course.

Interest & Usefulness of SSI

In terms of interest and usefulness of SSI, -as evident from the non-significant interaction effect- the course resulted in similar changes for both PSTs and PSSTs, Wilks Lambda = .99, F (1, 84) = .95, p = .334, partial eta squared = .01. This means that the impact of the course on interest and usefulness of SSI does not differ in terms of the majors. The main effect for time signified that SSI course yielded a significant increase in interest and usefulness of SSI (Wilks Lambda = .85, F (1, 84) = 14.32, p < .001, partial eta squared = .15) in both groups. Bonferroni-adjusted post-hoc comparison illustrated that PST' interest and usefulness of SSI scores significantly increased after SSI course, F (1, 84) = 15.21, p < .001, partial eta squared = .15. Although PSSTs' interest and usefulness of SSI scores increased after SSI course (mean difference = .11, CI: -0.01 to 0.23), this increase did not reach statistical significance, F (1, 84) = 3.15, p = .080, partial eta squared = .04.

Anxiety towards SSI

In terms of anxiety towards SSI, the result of mixed between-within subjects ANOVA demonstrated that the interaction between group and time was not statistically significant. That is, SSI course yielded similar change for PSTs and PSSTs on anxiety towards SSI. (Wilks Lambda = 1.00, F (1, 84) = .00, p = .958, partial eta squared < .001). The main effect for time indicated that SSI course did not change participants' anxiety towards SSI scores significantly in either group (Wilks Lambda = 1.00, F (1, 84) = .12, p = .730, partial eta squared < .001). A summary of mixed between-within subjects ANOVAs are given at Table 5.

Table 5. Summary of mixed between-within subjects ANOVAs

Source	*df*	*F*	*Partial* η^2	*p*
Interaction Effect				
Liking of SSI	1	.01	.00	.926
Interest & usefulness of SSI	1	.95	.01	.334
Anxiety towards SSI	1	.00	.00	.000
Error df			84	
Within Subjects				
Liking of SSI	1	32.37	.28	.000
Interest & usefulness of SSI	1	14.32	.15	.000
Anxiety towards SSI	1	.12	.00	.000
Error df			84	
Between Subjects				
Liking of SSI	1	1.72	.02	.193
Interest & usefulness of SSI	1	4.60	.05	.035
Anxiety towards SSI	1	.11	.00	.737
Error df			84	

Discussion

In the present study, we aimed to enhance PTs' attitudes towards SSI. To achieve this, we designed a semester-long SSI course in which PTs participated in argumentation and role playing on a selected SSI after completing teacher guided classroom activities. We investigated the effect of SSI course on PTs' attitudes and examined whether this effect differs for PTs in science education and non-science education majors. Since SSI was included in elementary science and social science curriculum, both groups of teachers are expected to provide sufficient guidance to their students' while teaching SSI. Therefore, we selected PST as science education group and PSST as non-science education group to observe the changes in their attitudes towards SSI. Attitude towards SSI was examined under three dimensions, namely liking of SSI, interest and usefulness of SSI, and anxiety towards SSI. Preliminary analyses showed that, before taking the course, both groups have moderate levels of interest and liking of SSI while they have a low level of anxiety.

The first finding of this study showed that both groups of PTs similarly benefitted from the SSI course. After taking the SSI course, enhancements were observed in their liking of SSI, and interest and usefulness of SSI scores, while there was no change in both groups' anxiety towards SSI scores. To account for this improvement in their interest and liking of SSI, the nature of activities appears to be the primary reason. In designing SSI course, we followed the main strategies in a series of research studies that made use of different SSI. Argumentation, as one of them, is used widely in many studies to enhance individuals' skills on the development of arguments and justifications to discuss SSI (e.g. Dawson & Venville, 2013; Erduran, Simon, & Osborne, 2004; Patronis, Potari, & Spiliotopoulou, 1999).

Argumentation is mostly incorporated into decision-making activities in the literature. In Patronis et al.'s (1999) study, students formed arguments to make decisions about a road construction in their local area. A similar strategy was also used in the study conducted by Jime´nez-Aleixandre (2002) who let the students engage in argumentation and decision making process about an environmental issue. It is clear from these studies that argumentation and decision-making activities quite-well accompanied with socioscientific issues. Inspired by such examples from the literature, the SSI course in this study involved small group activities in which students formed arguments and try to reach a decision on the SSI they selected. Since Khishfe (2012) suggested that socioscientific issues that are more relevant to students have more potential to initiate interest, we asked them to select an SSI which were most relevant to them. On the other hand, while anxiety scores increased in some amount in both groups, the changes were not statistically significant. At the beginning, we expected that engaging in SSI through different classroom activities may reduce their anxiety toward SSI because they have become informed about several of SSI. However, as mentioned, this is not the result that we found. The reason for the slight increase in anxiety scores can be attributed to the nature of specific SSI. That is socioscientific issues such as abortion, sperm bank, mother's milk bank, euthanasia, and career maternity are topics that are very sensitive in terms of religion. Having thought the religious beliefs of Turkish citizens, it is rational that the anxiety scores did not reduce. However, this finding is not disappointing since they already had low levels of concern and worry about SSI before the course.

One key finding of this study is that preservice teachers' interests and liking of SSI increased in both groups after participating in SSI course. The goal of the course was to educate PTs' as informed citizens about SSI and to enhance their attitudes towards SSI. Moreover, we aimed to prepare them to argue and form opinions based on different aspects of socioscientific issues. Thus, within the course, they learned how to present arguments for and against the issue under discussion. Therefore, we can conclude that the discussions and the activities in the course were effective in fostering teacher candidates' interest and usefulness of SSI as well as liking of SSI. Another reason for this improvement may be due to the fact that they were not involved in student directed group activities without preparation. Before each group's discussion, group members searched for the SSI they have chosen. This let them have prior knowledge about the issue. To be knowledgeable about the issue increases students' interest in the issue and helps them form arguments (Khishfe, 2012; Mason & Scirica, 2006).

We know that SSI is important and has been included in many nation's curricula of different disciplines. Scholars accept that being able to negotiate and reach a possible solution on SSI are skills that scientifically literate citizens should have (e.g. Patronis et al., 1999). Therefore, obtaining similar findings for both science education and non-science education groups is promising for raising scientifically literate citizens. SSI course nearly equally improved these groups' attitudes towards SSI. Having a higher level of science background may not be a prerequisite to make investigations about SSI and discuss with others who had different points of views. Since both groups of participants were adults at undergraduate level, they are expected to have fundamental skills in searching and discussing the social aspects of scientific phenomena. Thus, regardless of the background science knowledge, both groups of PTs increased their interest and liking of SSI, and maintain their anxiety about SSI in low level. According to Topçu (2015), in order to teach SSI teachers should have sufficient subject matter knowledge, be aware of the social aspects of the SSI, and effectively guide and contribute students' learning process. With the help of the SSI course, PTs' interest and liking of SSI can be increased within the teacher education programs before they started to teach SSI in their classrooms. Although teachers are not expected to know everything about a specific SSI, they should know plenty of scientific concepts related to that SSI (Topçu, 2015). In this study, PTs had the chance of learning about a wide range of SSI and they were expected to deeply learn at least one of them during their discussions in the SSI course. Since we did not measure PTs' subject matter knowledge in the course of the study, we don't know whether this course increased their subject matter knowledge. However, they had the opportunity to observe and experience an SSI instruction in which they can take a model and implement similar activities during their inservice teaching to engage students in class discussions and to develop their critical thinking skills. In order to generalize these findings, replication of this study in different majors such as physics education, chemistry education, biology education, primary school education, and math education is needed. As the last word, based on our findings from different majors, we can suggest that including SSI course in teacher education program will be beneficial to enhance different major PTs' interest and liking of SSI and this, in turn, will help them include SSI as a context in their future classrooms. For this purpose, SSI course can be a part of teacher education programs to make PTs gain more experiences to discuss and learn about socially relevant issues (Topcu et al., 2014). A teacher is one of the most important factors among the school related variables to influence students' learning (Sanders, Wright, & Horn, 1997). Thus teachers' attitudes towards SSI seem important, as it is potential to influence their students' attitudes.

Implications and Limitations

This study has some implications for preservice teacher education. Firstly, teachers' attitudes towards SSI is important for their students to develop positive SSI attitudes. Therefore, while training preservice teachers, their attitudes should be developed through such courses.

This study showed that science background is not a decisive factor for the effectiveness of SSI course on increasing attitude towards SSI. It may be because of the education level of the participants of this study. Since they are university students, they should have some fundamental science content knowledge. Therefore, it can be expressed that having fundamental science background might be sufficient to understand the science lying behind the SSI, conduct research about SSI, to analyze the findings, and to participate in class discussions to defense an idea about SSI against others. Therefore, teacher educators should utilize similar activities while teaching complex and multidimensional science topics. Moreover, this course can be offered for other teacher education programs and disciplines. This is promising for increasing the number of scientifically literate people.

Lastly, we have some suggestions for future research. First, this study provided empirical evidence that SSI course can increase PTs' interest of SSI and liking of SSI. However, further research is needed to figure out how long this effect will last. Second, longitudinal studies are needed to explore how PTs' attitudes towards SSI will influence their students in their future classrooms. Lastly, the effect of such SSI courses on younger students (middle or high school students) may also be investigated to make sound inferences about the effect of such courses in earlier years.

Although this study has successfully demonstrated that the SSI course has improved PTs' attitudes towards SSI, it has limitations as well. It is unfortunate that this study did not include a comparison group, we could not compare the effectiveness of the classroom activities used in the SSI course with a different approach to teach SSI. Moreover, as we did not have control groups, more evidence is needed to conclude that the SSI course accounted for the increase in PTs' attitudes towards SSI. Lastly, the instrument used in this study (ATSIS) does not focus on a specific SSI, instead, it considers SSI in general. Therefore, it is not possible to explore participants' attitudes on a unique SSI. Their attitudes may change in some degree for specific SSI. We hope that taking into account these limitations, in future, studies will carry SSI studies one step further.

Note

All authors have equally contributed to this paper.

References

Alaçam-Akşit, A. C. (2011). Sınıf öğretmeni adaylarının sosyobilimsel konularla ve bu konuların öğretimiyle ilgili görüşleri [Primary school teachers' views about socioscientific isssues and teaching them]. Unpublished master thesis. Ege University, Turkey.

Barber, M. (2001). *A comparison of NEAB and Salters A-level Chemistry: Students views and achievements.* York, UK: University of York.

Cansiz, N., & Cansiz, M. (2015). Views and knowledge of preservice science teachers about nuclear power plants. *International Journal on New Trends in Education and Their Implications, 6*(2), 216-224.

Cebesoy, Ü. B., & Dönmez-Şahin, M. (2013). Investigating Pre-Service Science Teachers' Attitudes towards Socioscientific Issues in terms of Gender and Class Level. *Marmara University Journal of Educational Sciences, 37,* 100-117.

Dawson, V. & Venville, G. (2013). Introducing high school biology students to argumentation about socioscientific issues. *Canadian Journal of Science, Mathematics and Technology Education, 13*(4), 356-372.
DeBoer, G. E. (2011). The globalization of science education. *Journal of Research in Science Teaching, 48*(6), 567-591.
Erduran, S., Simon, S., & Osborne, J. (2004). TAPping into argumentation: Developments in the application of Toulmin's Argument Pattern for studying science discourse. *Science Education, 88*(6), 915–933.
Gogolin, L., & Swartz, F. (1992). A quantitative and qualitative inquiry into the attitudes toward science of nonscience college majors. *Journal of Research in Science Teaching, 29*(5), 487504.
Hofstein, A., Eilks, I., & Bybee, R. (2011). Societal issues and their importance for contemporary science education—A pedagogical justification and the state-of-the-art in Israel, Germany, and the USA. *International Journal of Science and Mathematics Education, 9*(6), 1459–1483.
Jime´nez-Aleixandre, M. P. (2002). Knowledge producers or knowledge consumers? Argumentation and decision making about environmental management. *International Journal of Science Education, 24*(11), 1171-1190.
Khishfe, R. (2012). Relationship between nature of science understandings and argumentation skills: A role for counterargument and contextual factors. *Journal of Research in Science Teaching, 49*(4), 489–514.
Lee, H., Chang, H., Choi, K., Kim, S.-W., & Zeidler, D. L. (2012). Developing character and values for global citizens: analysis of pre-service science teachers' moral reasoning on socioscientific issues. *International Journal of Science Education, 34*(6), 925–953.
Lee, M.-K., & Erdogan, I. (2007). The effect of science-technology-society teaching on students' attitudes toward science and certain aspects of creativity. *International Journal of Science Education, 11*, 1315–1327.
Maio, G., & Haddock, G. (2009). *The psychology of attitudes and attitude change.* SAGE Publications.
Mason, L., & Scirica, F. (2006). Prediction of students' argumentation skills about controversial topics by epistemological understanding. *Learning and Instruction, 16,* 492-509.
Massialas, B. G., Sprague, N. F., & Hurst, J. B. (1975). *Social Issues through inquiry: Coping in an age of crises.* Englewood Cliffs, N. J.:Prentice-Hall
Ministry of National Education of Turkey. (2013). *Science and technology curriculum of elementary schools (3th–8th grades).* Ankara: Board of Education.
Patronis, T., Potari, D., & Spiliotopoulou, V. (1999). Students' argumentation in decision-making on a socio-scientific issue: Implications for teaching. *International Journal of Science Education, 21*(7), 745-754.
Petty, R. E., & Cacioppo, J. T. (1996). *Attitudes and persuasion: Classic and contemporary approaches*. Boulder, CO: Westview Press.
Roberts, D.A. (2007). Scientific literacy/science literacy. In S.K. Abell, & N.G. Lederman (Eds.), *Handbook of research on science education* (pp. 729–780). Mahwah, NJ: Lawrence Erlbaum Associates.
Sadler, T. D. (2004). Informal reasoning regarding socioscientific issues: A critical review of research. *Journal of Research in Science Teaching, 41*(5), 513–536.
Sadler, T. D. (2009). Situated learning in science education: socio- scientific issues as contexts for practice. *Studies in Science Education, 45*(1), 1-42.
Sadler, T. D., Barab, S. A., & Scott, B. (2007). What do students gain by engaging in socioscientific inquiry? *Research in Science Education, 37*(4), 371–391.
Sadler, T. D. (2011). Socio-scientific issues-based education: What we know about science education in the context of SSI. In *Socio-scientific Issues in the Classroom* (pp. 355-369). Springer Netherlands.
Sanders, W. L., Wright, S. P., & Horn, S. P. (1997). Teacher and classroom context effects on student achievement: Implications for teacher evaluation. *Journal of Personnel Evaluation in Education, 11*(1), 57-67.
Soysal, Y. (2012). Sosyobilimsel argümantasyon kalitesine alan bilgisi düzeyinin etkisi: Genetiği değiştirilmiş organizmalar [Influence of content knowledge level to socioscientific argumentation quality: genetically modified organisms] Unpublished master thesis. Abant Izzet Baysal University, Turkey.
Sönmez, A., & Kılınç, A. (2012). Preservice science teachers' self-efficacy beliefs about teaching GM Foods: The potential effects of some psychometric factors. *Necatibey Journal of Science and Mathematics Education, 6*(2), 49-76.
Sürmeli, H., & Şahin, F. (2012). Preservice teachers' opinions and ethical perceptions in relation to cloning studies. *Çukurova University Faculty of Education* Journal, *41*(2), 76-86.
Topcu, M. S. (2010). Development of attitudes towards socioscientific issues scale for undergraduate students. *Evaluation & Research in Education, 23*(1), 51-67.
Topçu, M. S. (2015). S*osyobilimsel konular ve öğretimi [Socioscientific issues and teaching them]*. Pegem Akademi: Turkey.

Topcu, M. S., Mugaloglu, E. Z., & Guven, D. (2014). Socioscientific issues in science education: The case of Turkey. *Educational Sciences: Theory and Practice*, *14*(6), 2340-2348.

Topçu, M. S., Yilmaz-Tuzun, O., & Sadler, T. D. (2011). Turkish preservice science teachers' informal reasoning regarding socioscientific issues and the factors influencing their informal reasoning. *Journal of Science Teacher Education*, *22*(4), 313-332.

Yager, S.O., Lim, G., & Yager, R. (2006). The advantages of an STS approach over a typical textbook dominated approach in middle school science. *School Science and Mathematics*, *106,* 248–260.

Young, T. (1998). Student teachers' attitudes towards science (STATS). *Evaluation and Research in Education, 12*(2), 96111.

Zeidler, D. L., Sadler, T. D., Simmons, M. L., & Howes, E. V. (2005). Beyond STS: A research-based framework for socioscientific issues education. *Science Education*, *89*(3), 357–377.

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First Year Nursing Students' Coping Strategies in Stressful Clinical Practice Situations

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Abstract

Performing the social service professions, to which a profession of nurse includes, is considered one of the most stress-inducing jobs. The reason behind this is deep emotional involvement in contact with patient followed by responsibility for human health and life. The time dedicated to gaining knowledge and practical skills constitutes both a potential stress source for the nursing students and provides them with the opportunity to learn how to cope with it. This study aims at assessing the level of stress in difficult situations, differentiating the methods of stress coping and difficult situations for the nursing studies in the course of practical training. 110 first-year students of intramural studies at the Nursing Faculty, State Higher Vocational School in Tarnów (southern Poland) were surveyed using the research tools include the author's survey questionnaire, Perceived Stress Scale, Inventory to Measure Coping Strategies with Stress. Differences between variables were verified using the chi-square ($\chi2$) independence test and Mann - Whitney test. The adopted significance level was α=0.05. During the first practical training, the nursing students struggled with multiple difficult situation (and perceived moderate and high stress and their attempts to cope with stress were diversified. Increase in stress level was accompanied by higher frequency of stress copying strategies by avoidance behaviours ($\chi2$=7.59; p=0.02). Students in difficult situations have more frequently applied coping strategies involving focusing on the issue of concern rather than emotion-based strategies. One should develop active methods of coping with stress and difficult situations with the nursing students, including in particular these manifesting helplessness and avoidance behaviours.

Introduction

Nursing is included in professions associated with service and mission. In many cases, potential nursing students follow a stereotypical image which may not be verified until the first confrontation, during practical training in hospital in contact with the patient and therapeutic team. The first contact with a potential future profession in its natural environment is of a great significance to the students, sometimes even decisive for continuing their studies. It takes place during practical training in the basics of nursing. The training is held in the healthcare facilities and aims to optimise nursing skills. The students master their skills, including among others, welfare and hygiene activities, instrumental activities, interpersonal communication, cooperation with the therapeutic team, organisation of work on the ward, and performance of duties of the therapeutic team members. During this first practical training, students become aware that this profession is bound with stress. Providing social services, which includes the nursing profession, is considered one of the most stress-inducing jobs. The reason behind this is largely due to the deep emotional involvement in contact with patients, followed by responsibility for human health and life, and struggling with concerns of the patients and their families. Predispositions to performing the profession of nursing are associated with relevant personality features and ability to cope with stress, which in turn involves making the right decisions in difficult situations.

Stress appears in human life in practically all situations, in particular during studies. Striving towards stress reduction is a natural consequence of such an appearance. We may then speak about coping with stress. Use of stress coping strategies among humans remains highly diversified; one person attempts to tackle stress, whereas others confine themselves to managing stress symptoms. The first group takes a proactive/fighting attitude, whereas the second chooses a more defensive approach. The actions taken depend on multiple biological and psychical factors and coping with stress is considered an adaptive or preventive process. Study and work are potential stress sources and so the period of gaining knowledge and practical skills create a perfect opportunity for learning how to cope with stress. The methods applied by students in difficult situations change with the education process (Fornés-Vives, Garcia-Banda, Frias-Navarro & Rosales-Viladrich, 2016). Lo (2002) agree that social support counteracts stress effects and ensures the well-being of an individual. It is important to identify problems which appear during practical training in hospital to prevent the situations that lead to helplessness and avoidance behaviours. It can also raise awareness of teachers to the problems faced by students and can guide educators towards specific course design to improve curricula. This study aims to assess the level of stress and difficult situations, differentiating both the methods of stress coping and the difficult situations, for nursing studies in the course of practical training.

Method

The research was performed using the diagnostic poll and estimation method, surveying and scaling technique on 110 first-year students of intramural studies at the Nursing Faculty, State Higher Vocational School in Tarnów (southern Poland). The applied research tools include the author's survey questionnaire, Perceived Stress Scale by S. Cohen, T. Kamarck, R. Mermelstein adapted by Z. Juczyński and N. Ogińska-Bulik and Inventory to Measure Coping Strategies with Stress by S. Charles Carver adapted by Z. Juczyński and N. Ogińska-Bulik (2012). The author's survey questionnaire consisted of questions related to difficult situations. Perceived Stress Scale (PSS10) was used to assess the stress pressure related to the individual living situation throughout the last month. It consisted of 10 questions referring to subjective feelings and perceptions related to personal problems and events. The respondent answered each question by choosing from a 5-score scale (ranging from 'never' to 'very often'). The general scores were converted into standardised units (1 – 10 stens) and interpreted following the Scale key. A score ranging between 1 and 4 stens is considered low, between 7 and 10 stens – high, and between 5 and 6 stens – moderate.

The Inventory to Measure Coping Strategies with Stress (Mini-COPE) was used to assess the typical responses and perceptions in high stress conditions and difficult situations. It consisted of 28 statements included in 14 strategies for coping with stress and difficult situations, divided into 7 factors i.e. Active Coping (AC); Planning (PL); Positive Revaluation (PR); Seeking Support including: Searching for Emotional Support (SES) and Searching for Instrumental Support (SIS); Helplessness including: Use of Psychoactive Substances (UPS), Cessation of Activity (CA), and Blaming oneself (B); and Avoidance Behaviours including: Dealing with something (Dea), Denial (De) and Discharge (Di). Strategies such as Turn towards Religion (R), Acceptance (A) and Sense of Humour (SH) acted as independent factors. As a result of in-depth analysis of the results, the problem-focused strategies covering: Active Coping, Planning, Searching for Instrumental Support, and emotion-focused strategies covering Searching for Emotional Support, Turn towards Religion, and Denial were distinguished. The study covered 110 first-year students of intramural studies at the Nursing Faculty, State Higher Vocational School in Tarnów (southern Poland). The research was carried out in 2016 upon completion of practical training by the students, who participated in the study on a voluntary and anonymous basis. Differences between variables were verified using the chi-square ($\chi2$) independence test and Mann – Whitney test. The adopted significance level was $\alpha=0.05$. IBM SPSS Statistics 20 software was used for computation purposes.

Results and Discussion

Women constituted the vast majority of researched students (97.3%). The age of the researched population ranged from 20 to 29 years (M= 21.04, SD=1.41). Everyday difficulties during practical training were faced by 5.5% of students while 54.5% of students stated that difficulties occurred quite often, whereas according to 38.2% of them, difficult situations were rare. The PSS-10 scores demonstrated that 10.0% of the researched group perceived low stress, 30.0% of them perceived moderate stress, whereas as many as 60.0% of the respondents perceived suffering from high stress. Age of respondents had no impact on the level of perceived stress ($\chi2=3.24$; $p=.52$), however, it was observed that older individuals obtained a higher score in PSS-10. According to the Mini-COPE scale scores, when facing a stressful situation, the nursing students most often chose active coping or searching for emotional support strategies, followed by dealing with something or searching for instrumental support. Less frequently chosen strategies included planning, acceptance, positive revaluation, turn towards religion or denial. The least popular strategies covered cessation of actions, sense of humour or use of psycho-active substances. In difficult situations, students with a low level of perceived stress significantly more frequently turned towards coping strategies based on positive revaluation ($\chi2=13.88$; $p=.01$) or sense of humour ($\chi2=6.71$; $p=.03$). As the stress level grew, the frequency of adapting the coping strategies focused on discharge increased ($\chi2=7.59$; $p=.02$). The students indicated the following difficult situations: discrepancy between theory and practice (93.6%), insufficient number of performed nursing procedures

(76.4%), and inability to master a technique or already gained skills (75.5%). Less frustrating situations included absence of relevant equipment (74.5%) and performing needless (in their opinion) tasks (72.7%). These were followed by inability to provide effective aid to the patient (57.3%), poor health condition of the patient (54.5%), preparation of patient for the procedure (53.6%), patients' questions on their health condition (50.0%), and establishing contact with patients and experiencing the suffering of patients (46.4%). 45.5% of students pointed at lack of patient satisfaction from provided aid and 42.2% mentioned workplace organisation, whereas, 41.7% of respondents perceived a conversation on private issues of the patient as a difficult situation. Close physical contact with the patient was difficult for 40.9% of the respondents, 38.2% mentioned contact with the patient's family and observing the aseptics and antiseptics rules (38.2%). Establishing cooperation with medical personnel was difficult for 30.9% of the students.

Difficult Situations Related to Interpersonal Relations and Coping Strategies

The students specifying poor health condition of the patient or conversations about private issues of patients as difficult situations during practical training more often opted for coping strategies based on searching for instrumental support or dealing with something, similarly to the students facing difficulties in establishing contact with the patient.

Table 1. Coping strategies adopted by the researched nursing students in situations related to interpersonal relations

		AC	PL	PR	A	SH	R	SES	SIS	Dea	De	Di	UPS	CA	B
Poor health condition of the patient	**M**	2,39	2,13	1,57	1,80	0,83	1,26	2,33	2,31	2,30	1,19	1,68	0,58	0,97	1,34
	p	0.12	0.68	0.32	0.14	0.18	0.94	0.31	0.00	0.01	0.28	0.21	0.1	0.58	0.16
	χ^2	4,29	0,77	2,25	3,98	3,46	0,13	2,34	10,80	8,55	2,54	3,12	0,00	1,09	3,71
Establishing contact with patient	**M**	2,54	2,21	1,67	1,85	0,86	1,10	2,42	2,38	2,35	1,17	1,61	0,39	0,90	1,25
	p	0.00	0.13	0.18	0.40	0.97	0.05	0.01	0.00	0.00	0.04	0.31	0.15	0.01	0.19
	χ^2	12,10	4,02	3,43	1,83	0,06	6,04	7,94	14,50	12,00	6,04	2,29	3,86	8,38	3,31
Close physical contact with the patient	**M**	2,50	2,22	1,79	1,98	0,81	1,18	2,43	2,30	2,40	1,24	1,63	0,62	1,06	1,21
	p	0.01	0.08	0.25	0.43	0.69	0.40	0.01	0.00	0.00	0.22	0.22	0.49	0.49	0.12
	χ^2	7,99	5,12	2,80	1,68	0,73	1,81	9,48	11,80	13,00	2,99	2,98	1,44	1,42	4,26
Inability to provide effective aid	**M**	2,41	2,16	1,61	1,94	0,86	1,15	2,48	2,21	2,20	1,13	1,69	0,61	0,99	1,29
	p	0.08	0.34	0.61	0.24	0.69	0.06	0.01	0.11	0.39	0.9	0.27	0.54	0.85	0.11
	χ^2	5,04	2,16	0,97	2,87	0,75	5,54	9,97	4,34	1,86	0,20	2,59	1,24	0,34	4,47
Experiencing the suffering of patients	**M**	2,51	2,29	1,64	1,86	0,83	1,11	2,51	2,45	2,30	1,01	1,66	0,46	0,93	1,30
	p	0.00	0.00	0.9	0.88	0.74	0.01	0.00	0.00	0.03	0.41	0.59	0.47	0.66	0.76
	χ^2	10,40	11,90	0,21	0,26	0,59	10,80	11,00	22,40	7,04	1,77	1,04	1,53	0,84	0,55
Conversation on private issues	**M**	2,35	2,14	1,57	1,85	0,82	1,28	2,38	2,33	2,40	1,15	1,61	0,61	1,09	1,25
	p	0.62	0.77	0.43	0.85	0.09	0.97	0.29	0.01	0.00	0.57	0.73	0.28	0.25	0.11
	χ^2	0,97	0,51	1,68	0,33	4,77	0,07	2,48	9,31	14,40	1,13	0,64	2,55	2,76	4,39
Out at lack of patients satisfaction	**M**	2,41	2,13	1,58	1,76	0,87	1,21	2,44	2,27	2,40	1,16	1,68	0,58	0,98	1,28
	p	0.16	0.54	0.59	0.11	0.95	0.71	0.09	0.05	0.00	0.59	0.15	0.73	0.80	0.47
	χ^2	3,63	1,24	1,06	4,50	0,09	0,68	4,93	5,95	15,60	1,03	3,73	0,61	0,44	1,51
Patients`questions on their health condition	**M**	2,49	2,23	1,55	1,84	0,74	1,13	2,41	2,33	2,38	1,09	1,66	0,45	1,01	1,22
	p	0.01	0.01	0.17	0.63	0.06	0.03	0.06	0.01	0.00	0.57	0.41	0.26	0.88	0.03
	χ^2	8,97	7,83	3,52	0,91	5,76	6,83	5,49	10,50	13,60	1,13	1,81	2,71	0,25	6,99
Contact with patient`s family	**M**	2,60	2,29	1,73	1,92	0,79	1,10	2,46	2,39	2,42	1,30	1,64	0,48	1,05	1,26
	p	0.00	0.00	0.83	0.83	0.54	0.06	0.01	0.00	0.00	0.09	0.45	0.71	0.44	0.32
	χ^2	20,40	12,70	0,36	0,36	1,25	12,10	10,20	12,30	14,60	4,76	1,58	0,69	1,66	2,26
Establishing cooperation with Staff	**M**	2,65	2,34	1,69	1,97	0,82	1,09	2,54	2,46	2,43	1,24	1,75	0,43	1,00	1,34
	p	0.00	0.01	0.89	0.49	0.23	0.13	0.02	0.00	0.00	0.08	0.05	0.51	0.55	0.07
	χ^2	15,90	9,01	0,23	1,43	2,93	3,99	7,78	13,40	10,50	5,06	5,78	1,32	1,18	5,21

In addition, they chose the strategies based on active coping and searching for emotional support, followed by denial, cessation of activities, active coping, and turn towards religion. The students having a problem with close physical contact with the patient more frequently turned towards the coping strategies based on active coping, searching for support, and dealing with something. Emotional support was sought by the individuals perceiving an inability to provide effective aid to the patient as difficult. Lack of patient's satisfaction from provided aid resulted more frequently in coping by choosing a strategy based on dealing with something. The respondents facing stress when asked by the patient about their health condition or experiencing their suffering significantly more frequently attempted active coping, planning, and seeking support. The students having difficulties with contacting the patient's family and establishing cooperation with medical personnel more often turned towards active coping, planning, searching for emotional and instrumental support or dealing with something – see Table 1.

Difficult Situations Related to Working Environment and Coping Strategies

The students describing insufficient numbers of performed nursing procedures as difficult significantly more frequently coped in difficult situations by choosing the strategies based on seeking support. The individuals for whom inability to master a technique or already gained skills was difficult significantly more often chose the coping strategy based on active coping, planning, seeking support or dealing with something. Students pointing at discrepancies between theory and practice as difficult significantly more frequently chose the strategies based on active coping, planning, acceptance, and seeking support. In addition, the students facing difficulties with performing needless (in their opinion) tasks significantly more frequently turned towards active coping strategies, planning, and searching for instrumental support. The respondents describing absence of relevant equipment as a difficulty significantly more frequently chose a strategy based on searching for instrumental support or a denial strategy – see Table 2.

Table 2.Coping strategies adopted by the nursing students in difficult situations related to working environment during practical training

		AC	PL	PR	A	SH	R	SES	SIS	Dea	De	Di	UPS	CA	B
Insufficient numer of nursing procedures	**M**	2,33	2,11	1,64	1,85	0,95	1,35	2,38	2,25	2,22	1,12	1,62	0,59	0,98	1,32
	p	0.15	0.24	0.70	0.55	0.07	0.2	0.02	0.00	0.07	0.63	0.31	0.63	0.89	0.79
	Z	-1.45	-1.46	-1.47	-1.48	-1.49	-1.50	-1.51	-1.52	-1.53	-1.54	-1.55	-1.56	-1.57	-1.58
Inability to master a skill technique	**M**	2,37	2,14	1,66	1,81	0,89	1,28	2,37	2,24	2,22	1,10	1,61	0,54	0,98	1,34
	p	0.01	0.04	0.88	0.07	0.87	0.79	0.03	0.00	0.02	0.98	0.7	0.34	0.78	0.68
	Z	-2.81	-2.06	-0.15	-1.78	-0.16	-0.26	-2.11	-3.67	-2.35	-0.02	-0.38	-0.95	-0.27	-0.41
Discrepancy between theory and practice	**M**	2,35	2,13	1,65	1,91	0,90	1,27	2,34	2,17	2,14	1,06	1,59	0,51	0,94	1,32
	p	0.00	0.02	0.80	0.00	0.23	0.34	0.03	0.00	0.91	0.02	0.60	0.00	0.01	0.57
	Z	-2.95	-2.41	-0.25	-2.75	-1.19	-0.96	-2.22	-3.68	-0.11	-2.41	-0.52	-3.29	-2.45	-0.58
Performing needles tasks	**M**	2,39	2,17	1,59	1,86	0,91	1,19	2,32	2,22	2,21	1,13	1,62	0,54	0,97	1,31
	p	0.01	0.02	0.11	0.79	0.29	0.03	0.43	0.01	0.06	0.60	0.38	0.93	0.83	0.62
	Z	-2.59	-2.42	-1.58	-0.27	-1.05	-2.14	-0.79	-2.61	-1.88	-0.53	-0.87	-0.09	-0.21	-0.49
Absence of relevant equipment	**M**	2,32	2,13	1,60	1,89	0,94	1,27	2,30	2,20	2,20	1,19	1,63	0,57	1,03	1,33
	p	0.39	0.07	0.13	0.56	0.06	0.73	0.68	0.05	0.16	0.05	0.08	0.86	0.05	0.90
	Z	-0.86	-1.80	-1.52	-0.58	-1.84	-0.35	-0.41	-1.99	-1.39	-1.97	-1.75	-0.18	-1.92	-0.12

Difficult Situations Related to Instrumental Activities and Coping Strategies

As a result of score analysis, it was clear that the students having difficulties with performing hygienic activities significantly more often turned towards the strategies based on active coping, seeking support, dealing with something or denial. The individuals having problems with performing measurements responded more often with adopting a denial, discharge, or blaming oneself strategies. Students facing difficulties when preparing patients for the procedure significantly more frequently chose the strategies based on active coping, planning, seeking support, dealing with something or discharge. The individuals with difficulties in preparing the workplace significantly more frequently used the strategy based on active coping, planning, and seeking support in difficult situations. Among the students having difficulties with observing the aseptics and antiseptics rules, a significantly more frequent selection of coping strategy based on active coping, planning, seeking support, and dealing with something was observed – see Table 3.

Table 3. Coping strategies adopted by the researched nursing students in difficult situations related to instrumental activities during practical training

		AC	PL	PR	A	SH	R	SES	SIS	Dea	De	Di	UPS	CA	B
Hygienic activities	**M**	2,53	2,21	1,71	1,95	0,74	1,26	2,56	2,32	2,48	1,34	1,69	0,66	1,03	1,19
	p	0.02	0.21	0.53	0.52	0.18	0.96	0.00	0.03	0.00	0.05	0.26	0.31	0.49	0.17
	Z	-2.39	-1.25	-0.63	-0.65	-1.35	-0.05	-2.84	-2.21	-3.31	-1.99	-1.12	-1.02	-0.69	-1.37
Measurements	**M**	2,31	1,92	1,61	1,89	0,94	1,58	2,42	2,28	2,31	1,50	1,94	0,78	1,28	1,69
	p	0.66	0.16	0.93	0.96	0.72	0.11	0.37	0.23	0.38	0.02	0.01	0.26	0.08	0.00
	Z	-0.44	-1.39	-0.09	-0.05	-0.36	-1.58	-0.89	-1.19	-0.89	-2.42	-2.47	-1.14	-1.76	-2.92
Preparing the patient for the procedure	**M**	2,42	2,22	1,66	1,94	0,80	1,18	2,44	2,36	2,34	1,22	1,69	0,59	1,00	1,25
	p	0.03	0.01	0.87	0.32	0.15	0.07	0.01	0.00	0.00	0.08	0.03	0.38	0.58	0.07
	Z	-2.17	-2.45	-0.17	-1.00	-1.44	-1.81	-2.58	-4.14	-3.23	-1.75	-2.15	-0.87	-0.56	-1.83
Preparing the workplace	**M**	2,55	2,30	1,67	1,85	0,84	1,13	2,49	2,38	2,29	1,11	1,62	0,43	0,86	1,32
	p	0.00	0.00	0.82	0.64	0.47	0.05	0.01	0.00	0.06	0.84	0.77	0.23	0.16	0.54
	Z	-3.52	-3.14	-0.23	-0.47	-0.72	-1.99	-2.66	-3.45	-1.89	-0.20	-0.29	-1.19	-1.39	-0.61
Observing the aseptics and antiseptics rules	**M**	2,61	2,26	1,56	1,76	0,69	1,05	2,52	2,42	2,36	1,12	1,65	0,39	0,83	1,23
	p	0.00	0.02	0.20	0.06	0.02	0.01	0.00	0.00	0.01	0.73	0.45	0.14	0.09	0.1
	Z	-4.06	-2.26	-1.22	-1.86	-2.43	-2.65	-2.94	-3.59	-2.69	-0.34	-0.75	-1.47	-1.67	-1.67

Situations related to interpersonal contacts with the patient, patient's family, and medical personnel posed the most difficulties to the students, followed by those related to working environments and instrumental activities. The widest range of coping strategies was adopted by the respondents for difficulties resulting from discrepancies between theory and practice, establishing contact with the patient, and observing aseptics and antiseptics rules. The most common strategies include active coping and searching for emotional and informational support. Focus on emotions was observed only in the case of inability to provide effective aid to the patient. Some of the students manifested avoidance behaviours, in particular in the case of difficulties arising in interpersonal relations. The respondents displayed helplessness in the following difficult situations: performing measurements, patients' questions on their health condition, discrepancy between theory and practice, and establishing contact with the patient. The vast majority of students coped with difficulties by focusing on the problem rather than focusing on emotions. According to the stressor analysis, the most common strategy performed by the researchers was seeking suport.

Nursing students face various difficult situations, in particular during their first practical training on the ward. The diversity of these situations necessitates using different stress coping strategies. Our studies revealed the following difficult situations for the students: discrepancy between theory and practice (93.6%), insufficient number of performed nursing procedures (76.4%), inability to master a technique or already gained skills (75.5%). In studies performed by Bodys-Cupak, Majda, Zalewska-Puchała and Kamińska (2016) among students, the identified difficult situations included discrepancies between theory and practice, poor health condition of the patient, experiencing the suffering of the patients or inability to provide effective aid to the patient. The results of Kaneko and Momino studies (2015) show that the key stressors for Japanese nursing students were, for the most part, limited contact with teachers and instructors, inability to discuss the activities taken or receive support, lack of knowledge and skills, performing nursing activities, and interpersonal contact with the patient and their family or interdisciplinary team members. The authors of other studies (Gibbons, 2010; Jimenez, Navia-Osorio, & Diaz, 2010) confirm that students, apart from struggling with difficulties resulting from interpersonal contacts with teachers or members of interdisciplinary teams, point out at the following stressors: lacks of knowledge, uncertainty in performing their nursing activities, care of a dying patient or fear of failure. In turn, Sayedfatemi, Tafreshi and Hagani (2007), when assessing the stressors for nursing students, demonstrated that first year nursing students, when compared to the fourth year students, identify more interpersonal and environmental stress sources.

Students use different strategies for coping with stress in difficult situations. Our studies revealed that the most commonly adopted strategies are based on active coping, searching for emotional or instrumental support. The least frequent method adopted by students to cope with difficult situations was using psycho-active substances. Similar results were obtained by Fornes-Vives et al. (2016) and Sayedfatemi et al. (2007).
The results of research carried out by Kaneko and Momino (2015) enabled them to state that in difficult situations, students displayed mood worsening and passive attitudes which manifested in no activity in seeking support to solve the problems. The results of studies performed by Hirsch, Barlem, Tomaschewski-Barlem, Figueira, Lunardi, and Oliveira (2015) revealed that nursing students in Brazil manifested avoidance behaviours in stressful situations. Most of the respondents participating in research performed by Shiferaw, Anand and Nemera (2015) coped with stress by positive thinking, whereas the most common negative method for getting over stress was blaming oneself. Similarly,Yildiz Findik, Ozbas, Cavdar, Yildizeli Topcu and Onler (2015) observed that nursing students in Turkey manifested passive strategies of coping despite high levels of stress. Also, Alzayyat and Al-Gamal (2016) stated that Jordanian students using the avoidance or displacement strategies perceived higher stress levels. The vast majority of the students of medical faculties participating in the studies performed by Niknami, Dehghani, Bouraki, Kazemnejad and Soleimani (2015) in Iran applied a coping strategy consisting of focusing on a problem.

Our own studies revealed that students in difficult situations seek social and instrumental support. Other authors (Lo, 2002; Gibbons, 2010; Gibbons, Dempster, & Moutray, M., 2011) confirm that a leading and more positive strategy for coping with stress applied by students is seeking social support. This is very significant in assisting students to develop positive coping strategies and to use difficult situations as a source of mobilisation and find positive factors. The main limitation of this study is that data collection occurred at one point in time, rather than longitudinally. Also, participants in the study were mainly young women which could cause bias. The present study significantly extends prior research on associations between different situations for students and the coping strategies. Future research should also be undertaken at multiple universities.

Conclusions

During practical training in hospital wards, difficult situations appeared relatively frequently in slightly more than half of nursing students. The most frequent difficult situations for nursing students were in the area of interpersonal relations with the patient, their family, and personnel; less frequent were in the area of working environment and instrumental activities. The vast majority of nursing students perceived moderate and high stress and frequency of manifesting of avoidance behaviours increased significantly with growing stress levels. Nursing students adopted different strategies for coping with stress in difficult situations, with seeking support being the most frequent and helplessness the least frequent. Nursing students more frequently applied coping strategies focused on the problem rather than on emotions.

Recommendations

One should, therefore, develop active strategies for coping with stress and difficult situations in nursing students, in particular for those students manifesting helplessness in their actions and displaying avoidance behaviours.

References

Alzayyat, A. & Al-Gamal, E. (2016). Correlates of Stress and Coping among Jordanian Nursing Students duringClinical Practice in Psychiatric/Mental Health Course. *Stress Health*, 32 (4), 304-312. doi: 10.1002/smi.2606.

Bodys-Cupak, I., Majda, A., Zalewska-Puchała, J. & Kamińska, A. (2016). The impact of a sense of self-efficacy on the level of stress and the ways of coping with difficult situations in Polish nursing students. *Nurse Education Today*, 45, 102-107. http://dx.doi.org/10.1016/j.nedt.2016.07.04.

Fornés-Vives, J., Garcia-Banda, G., Frias-Navarro, D. & Rosales-Viladrich, G. (2016). Coping, stress, andpersonality in Spanish nursing students: *A longitudinal study.*36, 318-323. doi: 10.1016/j.nedt.2015.08.011.

Gibbons, C. (2010). Stress, coping and burn-out in nursing students. *Internal Journal of Nursing Studies*, 47 (10),1299-1309. Doi: 10.1016/j.ijnurstu.2010.02.015.

Gibbons, C., Dempster, M. & Moutray, M. (2011). Stress, coping and satisfaction in nursing students. *Journal of Advanced Nursing*, 67 (3), 621-632. doi: 10,1111/j.1365-2648.2010.05495.x.

Hirsch, C., D., Barlem, E., L., D., Tomaschewski-Barlem, J., G., Figueira, A., B., Lunardi, V., L. & Oliveira, A.,C., C. (2015). Predictors of stress and coping strategies adopted by nursing students, *Acta Paul. Enferm*. 28 (3), http://dx.doi.org/10.1590/1982-019401500038.

Jimenez, C., Navia-Osorio, P., M. & Diaz, C., V. (2010). Stress and health in novice and experienced nursingstudents. *Journal of Advanced Nursing*, 66(2), 442-455. doi:10.1111/j.1365- 2648.2009.05183.x.

Juczyński, Z. & Ogińska Bulik, N. (2009). *Narzędzia pomiaru stresu i radzenia sobie ze stresem*. Warszawa:Pracownia Testów Psychologicznych.

Kaneko, S. & Momino, K. (2015). Stress factors and coping behaviours in nursing students during FundamentalsClinical Training in Japan. *Internal Journal of Nursing Clinical Practice*, 2, 138-144.http://dx.doi.org/10.15344/2394-4978/2015/138.

Lo, R. (2002). A longitudinal study of perceived level of stress, coping and self-esteem of undergraduate nursingstudents: an Australian case study. *Journal of Advanced Nursing* 39 (2), 119-126.

Niknami, M., Dehghani, F., Bouraki, S., Kazemnejad, E. & Soleimani, R. (2015). An assessment of the stressorsand ways of coping in Iranian medical sciences students. *Iranian Journal Nursing Midwifery Reearches*. 20 (4), 521-5. doi: 10.4103/1735-9066.161009.

Sayedfatemi, N., Tafreshi, M. & Hagani, H. (2007). Experienced stressors and coping strategies among Iraniannursing students. *BMC Nurs*ing 6:11, doi: 10.1186/1472-6955-6-11.

Shiferaw, H., Anand, S. & Nemera, G. (2015). Stress and coping strategies among generic B.Sc. nursing studentsof Jimma University, South West Ethiopia, *International Journal of Recent Advances inMultidisciplinary Research* 2 (7): 511-517.

Wolf, L., Stidham, A., W. & Ross, R., (2015). Predictors of stress and Coping Strategies of US Accelerated vs.Generic Baccalaureate Nursing Students: An Embedded Mixed Methods Study. *Nurse EducationToday* 35, 201-205. doi: 10.1016/j.nedt.2014.07.005.

Yildiz Findik, U., Ozbas, A., Cavdar, I., Yildizeli Topcu, S. & Onler, E., (2015). Assessment of nursing students' stress levels and coping strategies in operating room practice. *Nurse Education Practice*, 15 (3), 192-5.doi: 10.1016/j.nepr.2014.11.008.

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Personal Professional Development Efforts of Science and Technology Teachers in their Fields

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Abstract

The aim of this study is to examine the personal professional development efforts of science and technology teachers in their fields with regard to some variables. These variables were determined as gender, year of seniority and sufficiency level of the laboratory equipment. Moreover, the relation between the actual efforts exerted by science and technology teachers and the ideal level of efforts to be exerted by them for personal professional development in their fields was examined. In this study, survey model was applied. Research population was composed of science and technology teachers working in the central district of Eskişehir, a province in Turkey. Sampling was not made and it was attempted to get in contact with all 189 teachers covered in the population. However, data could not be obtained from some teachers and therefore, sampling of the study consisted of 130 teachers. As a data collection tool, "Scale of the Personal Professional Development Efforts of Science and Technology Teachers in their Fields" developed by the researchers was utilised in the research. In the comparison by gender, independent samples t–test was utilised while Anova was used in the comparison by the year of seniority and sufficiency level of the laboratory equipment. When the results of the research are examined, it is seen that female teachers use communication skills more effectively than male teachers. Also, as the senior years of teachers increased, the frequency of using and updating the technology decreased.

Introduction

Aim of the teaching profession is to ensure that the future generations are raised as constructive, creative, good individuals, beneficial for his/her family and environment (Murray, 2012). Professional success of teachers and raising successful individuals are important for the construction of a better future for our country and for the promotion of economic welfare (Tekışık, 1987). This can be achieved only through training good teachers who are at the core of the quality of the education system (Wössmann, 2002; Nye, Konstantopoulos, & Hedges, 2004; OECD, 2005; Hanushek, 2008). Especially from the first day of their professional life, teachers are expected to refresh their knowledge continuously, keep up-to-date, and realise the tasks and responsibilities required to be a contemporary teacher (Darling-Hammond, 2006; Cochran-Smith & Lytle, 1999). Surely, a teacher who cannot adapt oneself to changes will not be able to contribute to the change of his/her students. According to Özkan (2003), personal development is the self-improvement process of an individual to advance or achieve his/her targets and objectives. Personal development is the positive advancement of an individual. As a person constitutes a whole intellectually, emotionally and stylistically, he/she also advances as a whole during his/her development process (Özkan, 2003; Çoruk, 2007). Bayram (2010) defines the professional development of the teachers as an activity or process aiming to create a positive effect on knowledge, skills and behaviours. Özden (2001) explains the primary objective of the professional development as keeping up-to-date and learning the necessary competences to better perform a profession, and improving the knowledge, skills and behaviours required for that profession. Professional development of an individual affects himself/herself, his/her organisation as well as his/her colleagues. Individual's adaptation to the developments and to the changes in his/her job and efforts to better perform his/her duties as well are addressed under the professional dimension of personal development.

Ercan (2010) summarises the four main dimensions addressing the professional development in general as follows:

- "Personal Development" covers communication skills, stress, time management and similar activities.

- “Field-based Development” involves the acquisition and improvement of the knowledge and skills required for the field.
- “Organisation-related Development” covers individual’s being informed about his/her organisation and its functioning; and the importance of feeling a being part of the organisation. Through this dimension, organisations may be ensured to provide a more qualified service.
- “Educational Development” is a dimension based on the improvement of the in-class performance of the instructor.

As stated in the study carried out by Ercan (2010) professional development has to cover certain dimensions. It is noted that personal development, one of these dimensions, is closely related with professional development. Considering that personal development covers communication skills, stress and time management, and similar attributes, development of these qualifications has a positive effect on the professional development of teachers. The reason is that the concepts addressed under personal development are all related to classroom management skills, required to be observed among teachers. In line with the improvement of these skills, teachers will enhance their professional development and will also gain professional experience. Accordingly, this experience will enable teachers to provide their students with more effective and efficient learning options. Therefore, these two almost interwoven concepts set forth the concept of personal professional development. Personal professional development is a concept pointing to the activities required to be undertaken by the teachers personally, in order to advance in their professions and to eliminate their professional shortcomings (such as reading Turkish or foreign books related to their fields of study, watching national or international TV programmes, and attending seminars, etc.)

Teaching means ensuring a relatively permanent change in the individual’s behaviours (Fidan, 2012). Upon the beginning of the first course, the education and training process starts in schools. Teachers who are among the most crucial parts of a school bear the responsibility of ensuring that the students benefit from this process. In order to facilitate the learning of the students and enable them to be successful in this process, teachers should provide the stimuli to ease learning in the educational environment. There are many definitions of the teaching profession. According to Erdem (1998), “teaching is a profession having contemporary, cultural, scientific and technological dimensions, based on field-specific expertise, knowledge and skills; and requiring continuous refreshment of the knowledge and professional practice.” Özbay (2008) stated three main conditions to be able to perform the teaching profession. These are listed as having field information about a specific field, knowledge and skills required to transfer this information to others, and personal characteristics to satisfy these two conditions together. Accordingly, if teachers bearing important duties in this sense cannot develop themselves, it is clear that they will fall behind the times and will not be of great benefit to their students and the society. Especially from the first day of their professional life, teachers should refresh their knowledge continuously, keep up-to-date, and realise the tasks and responsibilities required to be a contemporary teacher.

There are certain actions to be taken by each teacher qualified as contemporary. Öztop (1994) describes the actions which should be taken by a teacher to develop himself/herself both personally and professionally as follows: enhancement of the required academic knowledge; participation to in-service training courses, seminars, conferences, panels; utilisation of technology in every field of life; keeping up-to-date with the publications related to his/her profession and the current agenda; reading to have knowledge about philosophy and arts; personal development; ensuring coordination between the schools and other organisations; and communicating and interacting with his/her colleagues and students.

Cunningham and Turgut (1996) defined the characteristics of an effective science teacher, and accordingly he/she:

- promotes learning in the class and encourages good relations among the students, by being intimate,
- is creative,
- is informed about the content of the natural sciences, understands and applies its principles,
- associates the content of the science classes with the interests and experiences of the students, develops and encourages project work,
- assesses and expresses opinion about the current teaching practices; organises the work properly either as individually or in groups,
- applies various teaching practices according to the student groups,
- has the sufficient communication skills to enable students understand the science issues and interact with the scientific materials,
- ensures a balance among the scientific activities of different types (oral, written or applied),

- provides an active learning atmosphere for students,
- plans and orders science teaching,
- carries out the necessary measures to determine and assess the science learning of the students,
- works individually or in small groups and has the teaching skills,
- encourages students to ask questions of “How?, Why?, What if …?”,
- guides students to make explanations about the events by considering the cause and effect relations,
- safely plans experimental researches in the laboratory,
- associates out-of-class natural events with the science issues.

Although university education on teaching means being a qualified teacher, it is controversial whether this will be sufficient in the forthcoming years. Therefore, it is necessary that the teachers maintain their education while also working actively (Glathorn, Jones & Bullock, 2006). It is known and mentioned in various platforms in our country that the teachers should develop themselves. In the literature, there is not a sufficient number of scientific studies examining whether this can be achieved by the teachers or not. There is not any sanction in this regard for the teachers and similarly, the reward mechanism is not functioning effectively. Depending on this, it is up to conscience of teachers, who are one of the most important and effective parts of education, to achieve the objectives of enabling students to catch up with the era, opening up their horizons, encouraging and guiding them. As a result of the limited number of researches on the personal development and competences of students, it has been concluded that the level of personal development and professional competences of teachers is insufficient (Öztop, 1994; Balbağ, Yenilmez & Turgut, 2017). However, there is not any comprehensive study on the scope of these deficiencies.

Purpose of the Research

This research aims to determine how the personal professional development efforts of science and technology teachers in their fields change according to the variables of gender, year of seniority and sufficiency level of the laboratory equipment. Moreover, the relation between the actual efforts exerted by science and technology teachers and the ideal level of efforts to be exerted by them for personal professional development in their fields was examined. The scale utilised in this study was developed by us and the stages of this development process was published in another study (Bilgin & Balbağ, 2016). Therefore, this study was carried out as an application of another previously-developed scale. However, the results of the application dimension of this scale are rather important, as it provides information about the personal professional development of science and technology teachers in Turkey. By this means, it is considered that measures to promote the personal professional development of science and technology teachers may be taken. In this research, with the aim of determining the personal professional development efforts of science and technology teachers in primary schools, the variables of gender, year of seniority and sufficiency level of the laboratory equipment were examined by the below given sub-dimensions:

What is the difference among the scores of

- educational and cultural backgrounds,
- specialisation,
- keeping up-to-date with scientific developments,
- keeping up-to-date with technological developments,
- keeping up-to-date with the curriculum,
- keeping up-to-date with the media and publications, of science and technology teachers,
- How is the relation between the actual efforts and the ideal level of efforts of science and technology teachers for personal professional development in their fields?

In this research, the variables of gender, year of seniority and sufficiency level of the laboratory equipment were addressed and their differentiation was examined as per six sub-dimensions of the scale. These variables were selected specifically on purpose. The variables of gender and year of seniority were selected to be examined due to the feeling of burnout observed among the teachers in practicing their profession. The feeling of burnout may differ among people, by gender and by age. A research carried out by Ergin (1992) revealed that the feeling of burnout is more intense among women than men, and with regard to the personal achievement dimension, the idea of personal achievement is more intense among men than women. The feeling of burnout among teachers may be considered as an example of negative reaction to difficult teaching conditions, undisciplined students, teaching circumstances and lack of support by the management (Tümkaya, 1996). Moreover, factors such as disciplinary problems related to students, insensitivity among students, crowded classrooms, undesired appointments, role conflicts, and criticisms against the teachers may also lead to the feeling of burnout among teachers (Farber, 1984). This feeling negatively affects the personal health of the teacher as well as the education process by causing troubles in the services provided to students (Baysal, 1995). Results of the feeling of burnout may be exemplified as neglection of work, increasing tendency to quit work, deterioration of service quality, absenteeism without any permission, tendency to extend the duration of leave by receiving health report, worsening of the work or personal relations, unconformity, alienation to family members or to spouse, job dissatisfaction, tendency to feel sick groundlessly, increase in work accidents, etc. (Çam, 1992) The research carried out by Akçamete, Kaner & Sucuoğlu, (1998) revealed a high level of relation between job satisfaction and the feeling of burnout. High level of enervation and a motivation are observed among those experiencing dissatisfaction in the workplace. A motivation means the interruption of the professional development by teachers such as through nonchalance, in a way to negatively affect their students and themselves. From this perspective, gender and year of seniority are two different variables concerning the professional development of teachers. Moreover, considering the number of science and technology teachers in Turkey, it is seen that the number of female teachers is higher than that of male teachers (MEB, 2015). This may be interpreted that the desire and motivation to become a teacher are higher among women than men. In this regard, it was considered that the variable of gender may lead to a difference in terms of personal professional development. Sufficiency level of the laboratory equipment of the schools is another variable addressed in this study. In the previous years, laboratory practices in schools used to be carried out to prove the accuracy of the scientific information, but in the recent years, laboratories have begun to be considered as places where new information is discovered, and where research-based learning takes place (Hofstein & Lunetta, 1982). When laboratories are available in schools and when they are well-equipped, teachers may further develop their present skills and promote their personal development through various experiments and practices they will design. Therefore, we consider that this variable should be addressed in relation to professional development. Indeed, according to the research results, sufficiency level of the laboratory equipment of the schools affects the professional development of science and technology teachers. Besides, as the scale has a parallel structure in this study, the relation between the actual efforts and the ideal level of efforts of science and technology teachers for personal professional development in their fields was also examined. Although there are many studies for personal professional development, the key to this study is a detailed study of the personal professional development of science teachers' fields.

Method

Research Model and Universe Sample

This research was prepared on the basis of a survey model as it aims to determine the personal professional development efforts of science and technology teachers. “Scale of the Personal Professional Development Efforts of Science and Technology Teachers in their Fields” developed by the researchers (Bilgin & Balbağ, 2016) was utilized in the research. This scale is composed of 6 sub-dimensions and 27 items. Sub-dimensions are educational and cultural backgrounds, specialization, keeping up-to-date with scientific developments, keeping up-to-date with technological developments, keeping up-to-date with the curriculum and keeping up-to-date with the media and publications, respectively. Internal consistency Cronbach Alpha co-efficient of the scale varies between .64 and .83. Cronbach Alpha co-efficient in the overall scale is .82.

Research population is composed of science and technology teachers working in the primary schools in the central district of Eskişehir, in 2011-2012 school years. Sampling was not made and it was attempted to get in contact with all 189 teachers covered in the population. Population covers 189 science and technology teachers. To address quantitatively sufficient amount of data in the research, sampling was not performed and all the science and technology teachers in these schools were tried to be contacted. However, it was not possible to benefit from the whole population due to difficulties in transport, existence of teachers on leave, lack of willingness of some teachers. Therefore, research population was composed of 130 science and technology teachers. 82 female and 48 male science teachers participated in the research. This study constitutes a part of a post graduate research in the field of physical sciences. Accordingly, this research tried to set forth the personal professional development efforts of science and technology teachers. In developing the scale, items of the scale were shaped on the basis of the feedback from science and technology teachers. When required, the scale may be adapted to other branches of teaching. Research was carried out in Eskisehir, a province of Turkey. Eskisehir was selected as the level of quality and success in education activities there is higher in this province than the average of Turkey, and as it is located in the Central Anatolia Region, just in the middle of Turkey. Moreover, the mentioned post graduate thesis is carried out in a university in Eskisehir, Eskisehir is a more secure province in comparison to many other provinces in Turkey, educational activities in this province are carried out rather properly, and the data collection is cheaper and easier than in any other province. Table 1 presents the population and sample of the central district of Eskisehir, where the research was carried out.

Table 1. Demographic characteristics of the teachers in the sample

Variables		n	%
Gender	Female	82	63.1
	Male	48	36.9
Year of seniority	5 years and below	26	20
	6 - 10 years	30	23.1
	11 - 15 years	26	20
	16 - 20 years	16	12.3
	21 years and above	32	24.6
Sufficiency level of the laboratory equipment	Very Well	15	11.9
	Sufficient	73	57.9
	Insufficient or absent	42	30.2
	Total number of teachers	130	100

Table 1 displays the demographic characteristics of the teachers participating in the research. The variables here are gender, year of seniority and sufficiency level of the laboratory equipment.

Data Collection Tool

In this study, "Personal Professional Development Efforts Scale for Science and Technology Teachers Regarding Their Fields" was used. The scale developed by the researchers is in the form of a parallel form, and it has been prepared in a way to include the questions for science and technology teachers which request them to assess their personal professional development regarding their fields both ideally and personally in the same question. 5 point likert type grading is used in the scale. This grading is as follows: "Always (5), often (4), sometimes (3), rarely (2) and never (1)". Language and meaning validity study on Personal Professional Development Efforts Scale for Science and Technology Teachers Regarding Their Fields has been conducted by three voluntary Turkish teachers working in primary school. Study on content validity of the scale has been prepared by voluntary experts working as lecturers in primary education department of education sciences at education faculty of the university, 4 of whom are working in the curriculum and measuring-evaluation department at education sciences, and 5 of whom are working in primary school, math and science division at primary education department. The scale has been observed through varimax rotation method composing of 6 factors and 27 items. Mentioned factors are educational and cultural knowledge, specialisation, following scientific and technological developments, following curriculum, following media and publications. Internal consistency of 5 point likert scale has been determined with Cronbach Alpha coefficient. Cronbach Alpha coefficient of the sub-dimension scale ranges between .64 and .83, which is .82 throughout the scale. Depending on these, it can be stated that data collection tools are valid and reliable. This work is important in terms of scale in schools as it is the first application. The sub-dimensions of the scale of personal professional development efforts towards Science Teachers' Fields; Educational and cultural background, specialisation, keeping up-to-date with scientific developments, keeping up-to-date with technological developments, keeping up-to-date with the curriculum, keeping up-to-date with the media and publications and it is considered that the coverage of the scale with sufficient number of items belonging to sub-dimensions is high. It is thought that the construct validity of the measurement tool is high because the answers given by science teachers to the data collection tool can give a general impression of the level of personal professional development efforts.

Analysis of Data

Scales filled in by science and technology teachers in the primary schools in the central district of Eskişehir were examined one by one. The data obtained accordingly were examined by the genders, years of seniority of the teachers and the sufficiency level of the laboratory equipment of their schools. Statistical analyses were carried out through SPSS (Statistical Package for the Social Sciences) 18 package programme.

During the statistical analysis, firstly the normal distribution of data was addressed through Kolmogorov-Smirnov. Then, independent sample t-test was applied for variables with two categories and one-way ANOVA for variables with three or more categories. The differences between the groups in the result of the ANOVA test were determined using the Scheffe test. Lastly, correlation was established to examine the relation between the personal professional development expected to be observed in an ideal science and technology teacher and their actual personal professional development in their fields.

Findings

According to the results of Kolmogorov-Smirnov tests realised, there is a normal distribution of data and the variables are homogeneous. Accordingly, sub-problems were tried to be answered through independent sample t-test which was used to make comparisons by gender, scores obtained in the data collection tools, and one-way ANOVA which was used to make comparisons by the year of seniority, and the sufficiency level of the laboratory equipment. Moreover, correlation was established to examine the relation between the personal professional development expected to be observed in an ideal science and technology teacher and the actual personal professional development in their fields.

Examination of the Variable of Gender of the Science and Technology Teachers by the Sub-Dimensions

Variable of gender of the science and technology teachers was examined by sub-dimensions. Accordingly, there is not a statistically significant difference ($p>.05$) between the averages of the scores of educational and cultural backgrounds, specialisation, keeping up-to-date with scientific developments, keeping up-to-date with technological developments, keeping up-to-date with the curriculum and keeping up-to-date with the media and publications both for female and male teachers. Table 2 presents the results of the analysis.

Table 2. Examination of the variable of gender of the science and technology teachers by the sub-dimensions

Sub-dimensions	Gender	*n*	$\overline{X}$	*SS*	*t*	*p*
Educational and cultural background	Male	48	19.45	3.99	-.45	.64
	Female	82	19.78	3.77		
Specialisation	Male	48	14.81	4.80	-.78	.43
	Female	82	15.54	5.35		
Keeping up-to-date with scientific developments	Male	48	20.06	3.03	-1.78	.07
	Female	82	20.95	2.55		
Keeping up-to-date with technological developments	Male	48	11.85	2.32	.16	.86
	Female	82	11.79	1.78		
Keeping up-to-date with the curriculum	Male	48	11.66	2.35	-2.60	.01
	Female	82	12.64	1.88		
Keeping up-to-date with the media and publications	Male	48	9.79	2.09	-.25	.80
	Female	82	9.87	1.74		

$p<.05$

It may be stated that the gender variable does not differ by these sub-dimensions. However, in terms of the sub-dimension of keeping up-to-date with the curriculum, there is a statistically significant difference ($p<.05$) between the averages of the scores of female and male teachers. Depending on this finding, it may be said that the female teachers communicate more frequently with the teachers in their groups and try to learn more about the acquisitions.

Examination of the Variable of the Year of Seniority of the Science and Technology Teachers by the Sub-Dimensions

Variable of the year of seniority of the science and technology teachers was examined by sub-dimensions. Accordingly, in terms of the year of seniority of female and male teachers, there is not a statistically significant difference ($p>.05$) between the sub-dimension scores of educational and cultural backgrounds, specialisation, keeping up-to-date with the curriculum and keeping up-to-date with the media and publications. Table 3 presents the results of the analysis.

Table 3.Examination of the variable of the year of seniority of science and technology teachers by the sub-dimensions

	Year of Seniority	*n*	$\overline{X}$	*SS*	Var. K.	*KT*	*Sd*	*KO*	*F*	*p*	*GAF*
Educational and Cultural Background	5 years and below	26	19.54	3.50	Inter-groups	25.68	4	6.42	.43	.79	None
	6-10 years	30	20.27	4.06	Intra-groups	1883.42	125	15.07			
	11-15 years	26	19.92	4.59	Total	1909.11	129				
	16-20 years	16	18.88	3.10							
	21 years and above	32	19.38	3.72							
Specialisation	5 years and below	26	13.69	3.39	Inter-groups	83.59	4	20.90	.78	.54	None
	6-10 years	30	15.87	6.31	Intra-groups	3344.44	125	26.76			
	11-15 years	26	15.50	5.28	Total	3428.03	129				
	16-20 years	16	15.69	5.28							
	21 years and above	32	15.63	5.04							
Keeping up-to-date with scientific developments	5 years and below[a]	26	21.92	2.30	Inter-groups	131.73	4	32.93	4.82	.00	a-e, a-d
	6-10 years [b]	30	21.10	2.66	Intra-groups	854.80	125	6.84			
	11-15 years[c]	26	21.08	2.31	Total	986.53	129				
	16-20 years[d]	16	19.56	2.80							
	21 years and above[e]	32	19.28	2.93							
Keeping up-to-date with technological developments	5 years and below[a]	26	12.77	1.66	Inter-groups	43.67	4	10.92	2.90	.02	a-d
	6-10 years [b]	30	11.83	2.23	Intra-groups	469.90	125	3.76			
	11-15 years[c]	26	11.96	2.16	Total	513.57	129				
	16-20 years[d]	16	10.94	1.48							
	21 years and above[e]	32	11.34	1.86							
Keeping up-to-date with the curriculum	5 years and below	26	11.81	2.08	Inter-groups	11.68	4	2.92	.64	.63	None
	6-10 years	30	12.63	2.28	Intra-groups	566.79	125	4.53			
	11-15 years	26	12.19	1.74	Total	578.47	129				
	16-20 years	16	12.63	1.78							
	21 years and above	32	12.25	2.44							
Keeping up-to-date with the media and publications	5 years and below	26	9.85	1.76	Inter-groups	12.57	4	3.14	.89	.47	None
	6-10 years	30	9.73	1.87	Intra-groups	440.35	125	3.52			
	11-15 years	26	10.35	1.92	Total	452.92	129				
	16-20 years	16	9.25	1.61							
	21 years and above	32	9.84	2.05							

GAF: Difference among the Groups

$p<.05$

It may be stated that the scores of teachers with different years of seniority in these sub-dimensions are close to each other. However, there is a significant difference ($p<.05$) in terms of the year of seniority between sub-dimension scores of keeping up-to-date with scientific developments and keeping up-to-date with technological developments. As a result of the Scheffe test carried out to determine the reason of this difference, it was found out that the scores of teachers with 5 years of seniority or below in the sub-dimension of keeping up-to-date with scientific developments are significantly higher than those of the teachers with 16-20 years of seniority or above. Similarly, it was determined that the scores of teachers with 5 years of seniority or below in the sub-dimension of keeping up-to-date with technological developments are significantly higher than that of the teachers with 16-20 years of seniority or above.

Examination of the Variable of the Sufficiency Level of the Laboratory Equipment of the Schools of Science and Technology Teachers by the Sub-Dimensions

In terms of the sufficiency level of the laboratory equipment of the schools of science and technology teachers, there is not a significant difference(p>.05) between the sub-dimension scores of keeping up-to-date with scientific developments, keeping up-to-date with technological developments; keeping up-to-date with the curriculum and keeping up-to-date with the media and publications. Table 4 presents the results of the analysis.

Table 4.Examination of the variable of the sufficiency level of the laboratory equipment of the schools of science and technology teachers by the sub-dimensions

	Laboratory	*n*	$\bar{X}$	*SS*	Var. K.	*KT*	*Sd*	*KO*	*F*	*p*	*GAF*
Educational and Cultural Background	Very well [a]	15	22.00	4.36	Inter-groups	116.22	2	58.11	4.12	.01	**b-a**
	Sufficient [b]	73	19.01	3.49	Intra-groups	1792.89	127	14.12			
	Insufficient or absent [c]	42	19.95	3.98	Total	1909.11	129				
Specialisation	Very well [a]	15	17.67	7.10	Inter-groups	277.81	2	138.90	5.60	.00	**b-a**
	Sufficient [b]	73	14.01	3.77	Intra-groups	3150.22	127	24.80			
	Insufficient or absent [c]	42	16.62	5.88	Total	3428.03	129				
Keeping up-to-date with scientific developments	Very well	15	21.67	2.58	Inter-groups	26.41	2	13.20	1.75	.17	**None**
	Sufficient	73	20.29	2.82	Intra-groups	960.13	127	7.56			
	Insufficient or absent	42	20.83	2.68	Total	986.53	129				
Keeping up-to-date with technological developments	Very well	15	11.87	2.23	Inter-groups	.66	2	.33	.08	.92	**None**
	Sufficient	73	11.75	1.98	Intra-groups	512.91	127	4.04			
	Insufficient or absent	42	11.90	1.99	Total	513.57	129				
Keeping up-to-date with the curriculum	Very well	15	12.33	2.38	Inter-groups	10.48	2	5.24	1.17	.31	**None**
	Sufficient	73	12.51	2.05	Intra-groups	567.98	127	4.47			
	Insufficient or absent	42	11.88	2.13	Total	578.47	129				
Keeping up-to-date with the media and the publications	Very well	15	10.13	2.39	Inter-groups	1.73	2	.86	.24	.78	**None**
	Sufficient	73	9.85	1.79	Intra-groups	451.19	127	3.55			
	Insufficient or absent	42	9.74	1.85	Total	452.92	129				

GAF: Difference among the Groups

p<.05

Accordingly, it may be stated that the teachers working in schools with different sufficiency levels of the laboratory equipment obtained similar scores in these sub-dimensions. However, in terms of the sufficiency level of the laboratory equipment there is a significant difference (p<.05) between the sub-dimension scores of educational and cultural backgrounds, and specialisation. According to the results of the Scheffe test carried out to determine the reason of this difference, educational and cultural backgrounds, and specialisation scores of the teachers working in schools with a high level of sufficiency with regard to the laboratory equipment are significantly higher than that of teachers working in schools with a sufficient level of laboratory equipment.

Findings Regarding the Relation between the Ideal and Current Condition of the Personal Professional Developments of Science and Technology Teachers in Their Fields

It is observed that the coefficient between the total scores obtained from the test of personal professional development efforts ideally expected from science and technology teachers in their fields, and the total scores obtained from the test of personal professional development efforts currently exerted by science and technology teachers in their field was .41 (p<.05). Accordingly, a medium-level, positive and significant relation was determined between the ideal and current condition of the personal professional efforts of science and technology teachers in their fields. Based on this finding, it may be said that in line with an increase in the actual personal professional development efforts of science and technology teachers, they get closer to the ideal personal professional development efforts expected from science and technology teachers in their fields. Table 5 presents the relation between the personal professional development efforts ideally expected from science and technology teachers in their fields, and the current personal professional development efforts of science and technology teachers in their fields.

Results and Discussion

According to the results of the research concerning the sub-dimension of “educational and cultural backgrounds” of science and technology teachers, genders of the teachers are not regarded as a distinguishing factor. Different years of seniority do not lead to a difference in the educational and cultural backgrounds of teachers. However, sufficiency of the laboratory equipment of the schools creates a difference. It is seen that in line with an increase in the sufficiency level of the laboratory equipment, educational and cultural backgrounds are also enriched. Laboratory work enables understanding the nature of science, observing the practices and ensuring a more permanent learning among the students. In the overall world, laboratory work is carried out to introduce and present new information and to ensure conceptual learning (Garnett, 1995).Based on this perspective, laboratory work is important for the science classes. In order to perform practices in science laboratories, teachers should be trained well and put their knowledge into practice in the classes. Quality of the laboratory activities will improve when the teachers actually experience different experiments or develop themselves in this regard. Each practice will constitute experience for the next trial. By this means teachers will be able to design more successful and different experiments. Based on these, it may be said that in line with an increase in the years of seniority and in the number and variety of the experiments, laboratory work may become more efficient. Geçer (2005) carried out a study regarding this issue in his Master's thesis titled “Various Difficulties Encountered in Laboratory Applications in the Science Classes”. It was stated that teachers became distant to the laboratory due to their incompetence in these applications, which turned to unwillingness in students over time. It was also reported that as the year of experience increased and there was a fully equipped laboratory in schools, teachers' confidence in themselves also increased and they started to become interested in laboratory activities.

Differences between the genders and years of seniority of the science and technology teachers do not lead to a difference in the sub-dimension of “specialization”. However, different sufficiency levels of laboratory equipment of the schools create a difference. It is observed that in line with the increase in the sufficiency levels of laboratory equipment of the schools, teachers specialize more in their fields. A teacher working in a well-equipped school may desire to develop himself/herself more. By this means, teachers may feel themselves more effective and successful. According to the master’s thesis of Ülgener (2010) titled “Obstacles faced by Science and Technology Teachers during their Practices”, nearly 19% of the teachers marked in the survey that they cannot practice laboratory work. This high ratio is distressing for both science teachers and students. In order to diminish this ratio, self-development of the teachers in their fields is very important. In this study, it was observed that 95% of the schools in the research sample have laboratories. The cases that teachers cannot practice laboratory work in schools with sufficient and highly sufficient laboratory equipment may be interpreted as the result of incompetency and lack of knowledge of the teachers in this regard. In his paper on "the basic problems of our primary education", Demirtaş (1988) highlighted the importance of the environment and tools in instructional practices. According to Demirtaş, the problems that should be addressed in terms of instruction included arranging the instructional environment, obtaining instructional tools, and making sure that these tools appeal to students and can be easily understood.

In terms of the sub-dimension of “keeping up-to-date with the scientific developments”, gender and the sufficiency of laboratory equipment do not create a difference. However, different years of seniority lead to a difference. Accordingly, teachers with 5 years of seniority or below attach more importance to keeping up-to-date with scientific developments. In other words, in terms of the sub-dimension of “keeping up-to-date with the scientific developments teachers with 5 years of seniority or below are more successful than teachers with 6-10 years, 11-15 years, 16-20 years, 21 years of seniority and above. It may be stated that in line with an increase in the year of seniority, the desire to keep up-to-date with the innovations decreases. The reason of this may be the feeling of burnout increasing in time and the inadequate promotion and reward mechanisms. Avcı and Seferoğlu (2011) obtained similar results in their study on the feeling of burnout among the teachers in the information society. It is stated that one of the reasons of the lack of technology literacy among the teachers is related with the feeling of burnout. In his\her study, Ünal Bozcan (2010) reported that the difference in the use of technology among male and female teachers was in favour of the male teachers, which contradicts the results of the current study.

In the sub-dimension of “keeping up-to-date with the technological developments” of the science and technology teachers, gender and the sufficiency of laboratory equipment do not create a difference. However, teachers with 5 years of seniority or below keep up-to-date with the technological developments more than the other teachers. In line with an increase in the years of seniority, the level of keeping up-to-date with the technological developments decreases. Today, in an era of communication and information, it is important to be able to use computer, be informed through internet and make researches in the internet. Moreover, being informed and keeping up-to-date with the technological developments are also important for catching up with the era. According to the master’s thesis of Avcu (2011) on the acceptance and usage tendency of the secondary school teachers towards the Information and Communication Technologies (ICT), anxiety level of the teachers with 6-11 years of seniority or above for ICT is higher than that of teachers with 1-5 years of seniority or below. It may be stated that teachers with fewer years of seniority consider themselves more competent and desirous in the fields related with technology. It is observed that the results of this research are in line with the mentioned research. In his study on the relationship between educational administrators' attitudes towards computers and their self-efficacy, Baltacı (2008) found that the administrators whose year of service was 16 years or less had higher levels of using information and communication technologies than those whose year of service was 21 years and above. Besides, the administrators who worked for 10 years and less differed within their group, and as the year of service increased, the level of using information and communication technologies decreased.

Within the scope of the sub-dimension of “keeping up-to-date with the curriculum” of the science and technology teachers, year of seniority of the teachers, and the sufficiency of laboratory equipment do not constitute a distinguishing factor. However, findings point out that the scores of female teachers for keeping up-to-date with the curriculum are higher than male teachers. The study of Özabacı and Acat (2005) on the perception of personal features related with the teaching profession and the level that the teachers have these features indicated that female teachers attach more importance to communication skills. Nacar (2010) also obtained similar results in his research on the communication and inter-personal problem solving skills of the class teachers. Female teachers benefit from communication skills more, as they compare themselves with the other teachers and as they have acquired women’s role since the childhood.

In terms of the sub-dimension of “keeping up-to-date with the media and publications” of the science and technology teachers, differences in the gender and years of seniority of the teachers and differences in sufficiency of laboratory equipment of the schools do not create a difference. In other words, fields related with the media and publications do not constitute a difference among the teachers. The sub-dimension of keeping up-to-date with the media and publications covers watching national/foreign television programmes related with the field of work of the teachers, and keeping up-to-date with the scientific periodicals. Accordingly, within this framework, the fact that there is no difference among the teachers in terms of gender, year of seniority and different sufficiency levels of laboratory equipment may be addressed in another study. A large majority of the teachers may not be watching national/foreign television programmes related with their fields, or may not be keeping up-to-date with the scientific periodicals. Moreover, knowledge of a foreign language may also have an effect on this topic. In her Master's thesis titled "Teachers' Views on the Necessity of Foreign Language Education", Karakuş (2010) stated that foreign language education was necessary to follow technological developments. It was reported that the teachers found foreign language education necessary for professional development. There is a medium-level, positive and significant relation between the personal professional development efforts ideally expected from science and technology teachers in their fields, and the current personal professional development efforts of science and technology teachers in their fields.

Conclusion

When the findings of the research are considered in general, a significant difference is observed between the genders of the teachers and their scores of keeping up-to-date with the curriculum; year of seniority and the scores of keeping up-to-date with the scientific developments; the sufficiency level of the laboratory equipment of the schools and the scores of educational and cultural background and the scores of specialization. A medium-level, positive and significant relation is observed between the ideal and current condition of the personal professional efforts of science and technology teachers in their fields.

Accordingly, it is observed that in line with an increase in the personal professional development efforts of teachers in their fields, they get closer to the personal professional development efforts ideally expected from science and technology teachers in their fields. This can be interpreted as the result of a parallel improvement in the experience with the enhancement of the personal professional development in their fields, and the increase in self-confidence in a way to better promote self-development. As a result of the research, it is seen that female teachers use communication skills more effectively than male teachers. Also, as the senior years of teachers increased, the frequency of using and updating the technology decreased. Moreover, teachers working in schools with very well equipped laboratories are more interested in their field, and more desirous to specialize in their fields. This study will set a precedent for the examination of the personal professional development efforts of science and technology teachers in their fields and will be beneficial in revealing and improving the defective aspects of the Turkish education system.

Recommendations

In accordance with the findings obtained from the research, the below recommendations could be given:

- Promotion and reward mechanisms for teachers in the Turkish national education should be reviewed and re-structured in an aim to improve personal professional development in their fields.
- Efficient and effective in-service trainings on the rapidly changing technology and its utilisation may be provided to teachers. These trainings may be rendered more actively.
- Personal Professional developments of teachers in their fields may be examined on the basis of different variables.

Note

This study has been generated by Ayşegül Bilgin from Master’s Thesis “Personal Professional Development Efforts of Science and Technology Teachers Regarding Their Fields” submitted at “Institute of Educational Sciences, Eskişehir Osmangazi University” in 2014.

References

Akçamete, G., Kaner, S., & Sucuoğlu, B. (1998). Engelli ve normal çoçuklarla çalışan eğitim yöneticilerinin tükenmişlik ve iş doyumu arasındaki ilişkinin karşılaştırmalı olarak incelenmesi. VI. Ergonomi Kongresi, Milli Prodüktivite Merkezi Yayınları No: 622, Ankara.

Avcu, D. Ü. (2011). İlköğretim ikinci kademe öğretmenlerinin bilgi ve iletişim teknolojilerine ilişkin kabul ve kullanım niyetleri (Yüksek lisans tezi). YÖK (313933).

Avcı, Ü., & Seferoğlu, S. S. (2011). Bilgi toplumunda öğretmenin tükenmişliği: teknoloji kullanımı ve tükenmişliği önlemeye yönelik alınabilecek önlemler. Akdeniz Eğitim Araştırmaları Dergisi, 9, 13-26.

Balbağ, M.Z., Yenilmez, K. & Turgut, M. (2017). Personal Professional Development Efforts Scale for Middle School Mathematics Teachers: An Adaptation Study, International Journal of Instruction, 10(4), 325-342.

Baltacı, H. (2008). İlköğretim okullarında görev yapan yöneticilerin bilgisayar tutumları ile öz-yeterlilikleri arasındaki ilişkinin incelenmesi (Yüksek lisans tezi). YÖK (219563).

Bayram, D. (2010). Türkiye, ABD, Japonya, İngiltere ve Avustralya’da fen ve fizik öğretmenlerine yönelik mesleki gelişim programlarının karşılaştırılması, Ankara Üniversitesi, Eğitim Bilimleri Enstitüsü (Doktora tezi). YÖK (279928).

Baysal, A. (1995). Lise ve dengi okul öğretmenlerinde meslekte tükenmişliğe etki eden faktörler. Yayınlanmamış Doktora Tezi, Dokuz Eylül Üniversitesi Sosyal Bilimler Enstitüsü, İzmir.

Bilgin, A., & Balbağ, M.Z. (2016). Personal professional development efforts scale for science and technology teachers regarding their fields**,** Acta Didactica Napocensia, 9(2), 67-78.

Cochran-Smith, M., & Lytle, S.L. (1999). The teacher research movement: A decade later.Educational Researcher, 28(7), 15-25.

Cunningham, R. T., & Turgut, F. (1996). İlköğretim Fen Bilgisi Öğretimi. YÖK/Dünya Bankası Milli Eğitimi Geliştirme Projesi Hizmetöncesi Öğretmen Eğitimi.

Çam, O. (1992). Tükenmişlik envanterinin geçerlik ve güvenirliğinin araştırılması. VII. Ulusal Psikoloji Kongresi Bilimsel Çalışmaları El Kitabı, 155-166. Ankara.

Çoruk, A. (2007). Okul müdürlerinin kişisel gelişim çabaları ve birlikte çalıştığı öğretmenlerin kişisel gelişimlerine katkıları (Yüksek lisans tezi). YÖK (220520).

Darling-Hammond, L., (2006). “Constructing 21st-Century Teacher Education”, Journal of Teacher Education, Vol. 57, No. X, pp.1-15.

Demirtaş, A. (1988). Temel eğitimimizin temel sorunları. Hacettepe Üniversitesi Eğitim Fakültesi Dergisi, 3, 51- 63.

Ercan, S. (2010). Eskişehir Osmangazi Üniversitesi yabancı diller bölümündeki okutmanların mesleki ve öğretimsel gelişime yönelik görüşleri (Yüksek lisans tezi). YÖK (263141).

Erdem, M. (1998). Öğretmenlik mesleğine giriş. İstanbul: Alkım.

Ergin, C. (1992). Doktor ve hemşirelerde tükenmişlik ve Maslach Tükenmişlik Ölçeğinin uyarlanması. VII. Ulusal Psikoloji Kongresi Bilimsel Çalışmaları El Kitabı, 143-154. Ankara.

Farber, B. A. (1984). Stress and burnout in suburban teachers. Journal of Educational Research, 77(6), 325-332.

Fidan, N. (2012). Okulda öğrenme ve öğretme. Ankara: Pegem akademi.

Garnett, P. J. (1995). Refocusing the chemistry lab: A case for laboratory-based investigations. Australian Science Teachers Journal, 41(2), 26-33.

Glathorn, A. A., Jones, B., K., & Bullock, A. A. (2006). Developing highly qualified teachers: A handbook for school leader. California, Corwin Press.

Geçer, K. (2005). Fen bilgisi dersleri laboratuvar uygulamalarında karşılaşılan bazı güçlükler (Yüksek lisans tezi). YÖK (197616).

Hanushek, E. A. (2008). The Economic Benefits of Improved Teacher Quality. In N. C. Soguel & P. Jaccard (Eds.), Governance and Performance of Education Systems (pp. 107–135).

Hofstein, A., & Lunetta, V. N. (1982). The role of the laboratory in science teaching: Neglected aspects of research. Review of Educational Research, 52(2), 201–217.

Karakuş, G. (2010). Öğretmenlerin yabancı dil eğitiminin gerekliliğine ilişkin görüşleri (Yüksek lisans tezi). YÖK (273472).

MEB (2015). MEB Official Education Statistics. Retrieved from https://sgb.meb.gov.tr/istatistik/meb_istatistikleri_orgun_egitim_2014_2015.pdf, p.67.

Murray, J. (2012). “Performativity cultures and their effects on teacher educators’ work” Research in Teacher Education, 2(2), 19-23.

Nacar, F. S. (2010). Sınıf öğretmenlerinin iletişim ve kişilerarası problem çözme becerilerinin incelenmesi (Yüksek lisans tezi). YÖK (286038).

Nye, B., Konstantopoulos, S., & Hedges, L. V. (2004). How large are Teacher Effects? Educational Evaluation and Policy Analysis, 26, 237–257.

OECD. (2005). Teachers matter. Attracting, Developing and Retaining Effective Teachers. Paris: OECD.

Özabacı, N., & Acat, B. (2005). Öğretmen adaylarının kendi özellikleri ile ideal öğretmen özelliklerine dönük algılarının karşılaştırılması. Kuram ve Uygulamada Eğitim Yönetimi Dergisi, 42, 211-236.

Özbay, Y. (2008). Eğitim psikolojisi. Ankara: Pegem akademi.

Özden, M. C. (2001). Bireysel kariyer yönetimi-profesyonelin el kitabı. Ankara: Ümit.

Özkan, Z. (2003). Bilgeliğe yöneliş – Kişisel gelişimin dinamikleri. İstanbul: Hayat.

Öztop, S. (1994). Geleceğin Türkiye’sinde öğretmenin işlevi ne olmalıdır. Çağdaş Eğitim Dergisi, 204, 34–36.

Tekışık, H. H. (1987). Türkiye’de öğretmenlik mesleği ve sorunları. Hacettepe Eğitim Fakültesi Dergisi, 2(1), 24-33.

Tümkaya, S. (1996). Öğretmenlerdeki tükenmişlik görülen psikolojik belirtiler ve başaçıkma davranışları. Yayınlanmamış Doktora Tezi, Çukurova Üniversitesi Sosyal Bilimler Enstitüsü, Adana.

Ülgener, G. (2010). Fen ve teknoloji öğretmenlerinin uygulama çalışmaları yaparken karşılaştıkları engeller (Yüksek lisans tezi). YÖK (265557).

Ünal Bozcan, E. (2010). Eğitim öğretim faaliyetlerinde teknoloji kullanımı. Eğitim Teknolojileri Araştırmaları Dergisi, 1 (4), 1-13.
Wössmann, L. (2002). Schooling and the Quality of Human Capital. Berlin: Springer.

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A Study of Developing an Environmental Attitude Scale for Primary School Students

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Abstract

The aim of this research is to develop an instrument that measures environmental attitudes of third grade students. The study was completed in six stages: creating scale items, content validity study, item total and remaining item correlation study, determining item discrimination, determining construct validity study and examining the internal consistency reliability of Cronbach's Alpha. In this research, quantitative research methods and techniques were used. According to the data obtained from exploratory factor analysis, scale came under three sub-factors as "Positive Environmental Behaviors", "Environmental Knowledge and Awareness" and "Negative Environmental Behaviors". As a result of the confirmatory factor analysis, it is determined that chi square/df, RMSEA value and the other statistical significance levels are consistent with the collected data. Cronbach's Alpha coefficient was taken between 0.71-0.94 for sub-scales and 0.93 for the total scale. In the light of these data, it is concluded that the environmental attitude scale has the validity and reliability.

Introduction

Environment was basically defined as all of the natural and artificial elements that condition the human life (Keleş and Hamamcı, 2005). It is possible to say that environmental problems are one of the most important problems of today. In order for the current problems to be minimized and the future generations to live in a healthy place, the role of the educators is huge. Because, as gradually accumulating, wrong behaviors can lead to bigger problems. For that reason, it is crucial to raise environment conscious individuals, for not doing any mistakes at early ages, even if they seem minor and unimportant. For the first time in the world history, humankind seems to become a part of this process as a separate problem other than those originating from the world itself (Demir, 2016).

It is a fact that the education activities are important in the approaches on permanent solutions on environmental problems. Because, the easiest, cheapest and firmest way to develop such approaches, is to educate our children starting from early ages. Accordingly, raising individuals conscious and aware of environment comes out as the most effective way to solve those problems (Benli, Ay and Kahramanoğlu, 2011). It is clear that individuals with negative attitudes towards the environment will be inconsiderate towards environmental problems and will continue to pose problems to the environment (Uzun and Sağlam, 2006). Environmental condition in long-term, is related with the future generations to take care of the environment. In a report published by the Childhood Alliance, it is indicated that the childhood is a critical period in acquiring anxiety, interest, awareness, tendency, dignification and knowledge acquisition related to natural world. For this reason, it is crucial to start studies concerning the environment at early ages (Yaşaroğlu, 2012). Students who cannot develop positive attitudes regarding the environment at early ages may face the risk of not being able to develop positive attitudes for the rest of their lives. Provided that the student develops negative attitude at early ages, these negativities become permanent and lay the foundations of unwanted behaviors in the future. Positive attitude acquired at early ages, forms the basis of the following years (Chapman&Sharma, 2001; Erten, 2004; Gökçe, Kaya, Aktay and Özden, 2007).

The objective of this research is to develop a valid and reliable instrument that measures environmental attitudes of third grade students. Within this scope, it is aimed to develop an instrument including the dimensions of cognition, perception and behavior. Related literature review shows that there are many studies aimed at middle school, high school and university students, whereas there is no such environmental attitude scale including dimensions of cognition, perception and behavior aimed at elementary school students. So as to gain environment-oriented positive attitudes, the attitudes gained at earlier ages are important. It is emphasized in researches that the attitudes acquired at early ages will continue to be in the future (Chapman&Sharma, 2001; Erten, 2004; Gökçe and et al. 2007). Thus, it is important to develop such scale in order to emphasize the environmental education of children at early ages and measure to what extent they develop environmental consciousness, which is not included in the literature.

Sustainable development which is one of the learning sub-fields of Science-Technology-Society-Environment of Science lesson contains "enabling future generations to meet their needs by using natural resources economically, developing conscious on individual, society and economic benefits of an economical usage." (MEB, 2013). In order for sustainable development conscious to be improved, students have to hold the environmental attitude. It will be possible to reach a measuring instrument which shows to what extent this program succeeded in instilling the objectives of the program in the students. It also will help determine the environmental attitudes of the students who have not attended Science class since the class is introduced at the 3rd grade. There is a need for a scale that includes the dimensions of cognition, perception and behavior in regard to the importance of environmental attitude to be acquired at early ages. Individuals, who are conscious of environmental attitude, have to have the environmental knowledge, recognize the environmental problems, be sensitive to these problems and act accordingly.

Method

Study Group

Since this study is a scale development study, population and sample method had not been chosen. Study group was determined by easily accessible sampling method. The study group of the research consists of 416 third grade students studying in four elementary schools in 2014-2015 academic year in central district of Eskişehir. Demographic information of 416 voluntary participants of the study can be seen on Table 1.

Table 1. Distributions according to the demographic attributes of the study group

Variables		N	Mean
	F	198	47.6
Gender	M	209	50.2
	Unspecified	9	2.2
Total		416	100

In the sampling group, there are 198 male and 209 female students. 9 students did not mark the gender selection. Since 66 students did not fully complete the scale form, they were not included in the study group and thus, the study group regarded as 416 students. In this study, three point Likert scale was chosen since the study is conducted among the 3rd grades. Draft scale was prepared as three point Likert as Agree (3), Partially Agree (2), Disagree (1).

Creating the Scale Items

In order to develop data collection tool, Education Program of Science and 3rd grade Science Lesson books were examined. In accordance with "Sustainable Development" - one of the sub-learning fields of Science-Technology-Society-Environment, which includes the acquirements that take place in the educational program as *"Knows the environment and takes active roles in cleaning these places. Understands the importance of natural habitat on living creatures and takes precautions in order to save the natural habitat. Understands the importance of economical usage of the resources such as electric and water and acts accordingly. Understands the importance of the required situations for a healthy life and performs in daily life. Discusses the harms of waste batteries to the environment and actions to be taken about them."* and enables future generations to meet their needs by using natural resources economically, develops conscious on individual, society and economic benefits of an economical usage, a 65-item scale pool was created.

Content Validity Study

The main objective of this study is to provide content validity in order to put forward whether the developed scale reflects the behaviors of the items sufficiently or not. Within the framework of content validity, expert opinions were taken into consideration when determining the scale items whether they are enough by means of number and quality or not. Scale items were rearranged according to expert's suggestions. Draft scaling form consisting of 65 items was asked for three different experts' opinions. The experts consisted of Associate Professor of the department of School Teaching who had studies on science and environmental education, Associate Professor of the department of School Teaching who is a geography teacher and had environmental education studies and Assessment and Evaluation Expert (Associate Professor). Expert evaluation form was created and all the experts asked to evaluate the items on the draft form. Evaluations made as "has to be removed, revised or acceptable). Evaluations of three experts were examined and 5 items decided to be left out considering that they will not help scaling the environmental attitude.

The Study of Face Validity

"Face validity is defined as scaling the feature aimed to be scaled, the name of the measuring instrument, its instructions, organization and items and the questions reflecting this." (Büyüköztürk, 2004; p.117). In that study, two expert opinions were taken for face validity of the draft measuring instrument. Following the content and face validity, pilot testing was carried out with twenty students which did not take part in the sample group of the draft form. The unknown words by these students were determined. The synonyms were used or changes made on draft scaling form by writing the definitions in brackets. Validity and reliability analyses were performed on 416 primary third grade students. Draft scale was prepared as three-point Likert scale as Agree (3), Partially Agree (2), Disagree (1). For the item discrimination of scale items and for the determination of remaining item coefficient, Pearson's product moment correlation analysis was carried out and for the comparison of %27 subgroup and super group item points, independent samples t test was performed. In order to determine the construct validity, exploratory and then confirmatory factor analysis were carried out. For internal consistency, Cronbach's alpha coefficient was calculated. Validity and reliability calculations of the scale were conducted considering the SPSS and LISREL 8 programs.

Data Analysis

In research, before dealing with the data analysis collected by the data collection tool, measuring instruments were numerated from 1 to 416. After the numbering process, data were transferred to computer environment in accordance with the given numbers. Following the transfer, environmental attitude scale and validity and reliability of the sub dimensions were calculated in the SPSS 21 Windows package software. Besides, descriptive analysis of the scale such as percentage, arithmetic mean and standard deviation, were carried out. The significance level for statistical analyses on this research was determined as 0,01.

Findings

In order to determine the item scales by means of features to see how effective they are to discriminate the people, item total and item rest correlations on the collected data obtained from 416 students, were calculated. The obtained correlation coefficient is the validity coefficient of that item and it indicates its consistency with the overall test. The correlation coefficients obtained from the item total correlations changes from 0.12 to 0.73, whereas the correlation coefficients taken from the item rest correlations changes from 0.06 to 0.73. As a result of item total correlation, item 8 "If there is a recycling box, I throw my garbage on it." had been removed from the scale items since it had not regarded as statistically significant. As concluded from the item rest correlation, item 15 "Pollution of the sea only affects the animals living in the sea." And item 46 "I should not take part in cleaning the class." had been removed from the scale items since it had not regarded as statistically significant.

Table 2. Item total and item rest correlation coefficients of the item scale

	Item Total	**Item Rest**
Item Number	***r***	***r***
1. It is important for our future to have an economical use of resources (water, electricity, natural gas, etc.).	.68**	.66**
2. Clean air is important for our health.	.70**	.69**
3. Environmental pollution only affects human life negatively.	.25**	.21**
4. Clean environment makes me happy.	.70**	.69**

5. Trees and flowers need clean water.	.64**	.63**
6. Damage to forests affects the natural life negatively.	.30**	.26**
7. Environmental pollution is dangerous to all living creatures.	.56**	.54**
8. If there is a recycling box, I throw my garbage on it.	.12	.06
9. I discuss current environmental problems with my family.	.50**	.47**
10. Recycling contributes to the national economy.	.52**	.49**
11. All living creatures need a clean world.	.67**	.65**
12. Protecting the nature is important for endangered animals.	.45**	.42**
13. I separate trashes at home for throwing them on recycling boxes.	.48**	.45**
14. I feed street animals.	.50**	.47**
15. Pollution of the sea only affects the animals living in the sea.	.15*	.09
16. Random disposal of used batteries damages the environment.	.51**	.48**
17. I know the plants in my environment.	.36**	.32**
18. I love animals.	.66**	.65**
19. We may have trouble finding clean drinking water in the future.	.36**	.32**
20. Recycling is important.	.65**	.64**
21. We do less harm to environment when we use public transport instead of cars.	.26**	.20**
22. I know the things that can be recycled.	.44**	.42**
23. I know where the recycling boxes are for used batteries.	.50**	.47**
24. I do not throw garbage on street.	.66**	.64**
25. It is not my responsibility to protect the environment.	.41**	.38**
26. The garbage thrown away at school attracts my notice.	.50**	.48**
27. I don't be upset about the pollution in my environment.	.46**	.43**
28. I use water economically.	.44**	.42**
29. Trees and flowers need clean soil.	.73**	.72**
30. I do my part regarding the cleanliness of our class.	.63**	.62**
31. I get upset about fishes living in dirty water.	.57**	.55**
32. I watch documentaries about living creatures.	.43**	.40**
33. I would like to participate in environmental cleaning activities.	.65**	.63**
34. I do not damage trees.	70**	.69**
35. We should protect the nature.	.72**	.71**
36. I take part in environmental activities.	.49**	.46**
37. I talk about current environmental problems with my friends.	.45**	.42**
38. Environmental pollution affects the habitats of some living things.	.36**	.32**
39. Unconscious hunting causes some animals to be extinct.	.39**	.35**
40. I don't do harm to animals.	.69*	.67**
41. I know the animals in the environment I live.	.56**	.53**
42. I enjoy watching documentaries about living creatures.	.40**	.37**
43. The lights left open do not attract my attention	.23**	.18**
44. People throwing litter makes me sad.	.64**	.62**
45. I would like to plant trees.	.66**	.65**
46. I should not take part in cleaning the class.	.17**	.12
47. Damaging forests do not affect the natural life negatively.	.28**	.23**
48. Animal extinction makes me sad.	.59**	.57**
49. When I see a flowing faucet, I close it.	.63**	.62**
50. I would like to grow plants.	.51**	.49**

51. I do harm to animals.	.47**	.44**
52. I plant trees.	.53**	.50**
53. Garbage on street attracts my notice.	.62**	.60**
54. I would like to work for my environment to be clean.	.60**	.59**
55. I feel sorry when I see the wasted taps.	.59**	.57**
56. I throw waste pills on waste battery box.	.66**	.64**
57. Feeding animals makes me happy.	.67**	.66**
58. I turn off the lights that are left on.	.71**	.69**
59. I do not use the water economically.	.28**	.24**
60. I do not harm the plants.	.58**	.57**

n=416 *p<.05 **p<.01

Item Discrimination Power

In order to determine the discriminating power of the items on the scale, item analysis was made. For every item, obtained points were sorted as biggest to smallest and independent group t test was performed for %27 top and bottom parts. In Table 3, independent group t test results which had been carried out so as to determine the item discriminating powers are given below.

Table 3. Results of the independent group T test results determining the item discrimination powers

Item No	***t***
1. It is important for our future to have an economical use of resources (water, electricity, natural gas, etc.).	4.806*
2. Clean air is important for our health.	5.070*
3. Environmental pollution only affects human life negatively.	17.356*
4. Clean environment makes me happy.	4.967*
5. Trees and flowers need clean water.	5.114*
6. Damage to forests affects the natural life negatively.	17.525*
7. Environmental pollution is dangerous to all living creatures.	7.016*
9. I talk about current environmental problems with my family.	16.182*
10. Recycling contributes to the national economy.	7.683*
11. All living creatures need a clean world.	5.689*
12. Protecting the nature is important for endangered animals.	1.459
13. I separate trashes at home for throwing them in recycling bins.	16.654*
14. I feed street animals.	11.175*
16. Random disposal of used batteries damages the environment.	7.975*
17. I know the plants in my environment.	15.989*
18. I love animals.	7.067*
19. We may have trouble finding clean drinking water in the future.	16.776*
20. Recycling is important.	4.410*
21. We do less harm to environment when we use public transport instead of cars.	24.269*
22. I know the things that can be recycled in my environment.	11.535*
23. I know where the recycling boxes are for used batteries.	16.029*
24. I do not throw garbage on street.	6.342*
25. It is not my responsibility to protect the environment.	9.376*
26. The garbage thrown away at school attracts my notice.	8.210*
27. I don’t be upset about the pollution in my environment.	6.742*
28. I use water economically.	8.080*

29. Trees and flowers need clean soil.	5.145*
30. I do my part regarding the cleanliness of our class.	6.459*
31. I get upset about fishes living in dirty water.	7.046*
32. I watch documentaries about living creatures.	15.986*
33. I would like to participate in environmental cleaning activities.	10.621*
34. I do not damage trees.	4.980*
35. We should protect the nature.	4.737*
36. I take part in environmental activities.	16.165*
37. I talk about current environmental problems with my friends.	16.437*
38. Environmental pollution affects the habitats of some living things.	9.586*
39. Unconscious hunting causes some animals to be extinct.	10.278*
40. I don’t do harm to animals.	4.600*
41. I know the animals in the environment I live.	15.989*
42. I enjoy watching documentaries about living creatures.	16.062*
43. The lights left open do not attract my attention	13.382*
44. People throwing litter makes me sad.	7.842*
45. I would like to plant trees.	6.517*
47. Damaging forests do not affect the natural life negatively.	19.811*
48. Animal extinction makes me sad.	7.846*
49. When I see a flowing faucet, I close it.	6.183*
50. I would like to grow plants.	6.991*
51. I do harm to animals.	5.529*
52. I plant trees.	10.894*
53. Garbage on street attracts my notice.	8.000*
54. I would like to work for my environment to be clean.	8.112*
55. I feel sorry when I see the wasted taps.	7.704*
56. I throw waste pills on waste battery box.	6.279*
57. Feeding animals makes me happy.	6.630*
58. I turn off the lights that are left on.	5.345*
59. I do not use the water economically.	10.914*
60. I do not harm the plants.	4.778*

n= 230, SD= 124 , *p<.01

According to the values on Table 3, item 12 “Protecting the nature is important for endangered animals.” had been removed since the item is not p<.01 and do not have statistical significance.

Construct Validity

In order to determine the construct validity of the item, factor analysis was carried out. Factor analysis is performed in order to find out whether the scale items separated into fewer factors which keep each other out or not. Items gathering in the same group are named according to their contents (Baloğlu, Karadağ ve Karaman, 2008). In this study, two factor analyses in literature were used. Primarily, exploratory factor analysis had been carried out, and then confirmatory factor analysis was performed. Kaiser-Meyer-Oklin and Bartlet values required for determining the construct validity of the scale were determined. Since KMO= .908 and Barlett value is p<.01, it is shown that the data set is suitable for factor analysis. This indicates that there are high correlations between the variables, in other words, Environmental Attitude Scale is suitable for factor analysis. Since KMO values are over 0.60, it includes the acceptable values. If KMO values are calculated high, Barlett values will be high accordingly. If the two of them have high values, then it will indicate the utility of the factor analysis and also show that the correlation values between the items are high (Kalaycı 2008). Varimax Rotation

Technique is preferred since the scale has a multifactor structure and it is aimed at the generalizability of the data obtained (Acat, Tüken&Karadağ, 2010). According to Büyüköztürk (2004), if the item-total correlation is positive and high; it indicates that the items on the scale exemplify similar behaviors and that the internal consistency of the test is high. Generally, item-total correlations valued .30 and higher contribute to the measurement of the overall measure of the scale. If one variable is below the factor load of 0.30; it is considered as low level and these items have to be removed from the scale (Kline, 1994). As a result of the factor analysis carried out, items with inappropriate factor loadings were removed from the scale (factor load <0.30). In Table 4, three sub-factors and item loadings that came out as a result of the exploratory factor analysis are given.

Table 4. The results of exploratory factor analysis related to the scales

Item	***1.***	***Item***	***2.***	***Item***	***3.***
35. We should protect the nature.	.85				
40. I don’t do harm to animals	.79				
34. I do not damage trees.	.78				
58. I turn off the lights that are left on.	.76				
2. Clean air is important for our health.	.75				
4. Clean environment makes me happy.	.75				
49. When I see a flowing faucet, I close it.	.74				
24. I do not throw garbage on street.	.73				
11. All living creatures need a clean world.	.73				
57. Feeding animals makes me happy.	.70				
60. I do not harm the plants.	.69				
5. Trees and flowers need clean water.	.69				
56. I throw waste pills on waste battery box.	.68				
20. Recycling is important.	.67				
30. I do my part regarding the cleanliness of our class.	.66				
1 It is important for our future to have an economical use of resources (water, electricity, natural gas, etc.).	.63				
18. I love animals..	.62				
48. Animal extinction makes me sad.	.59				
31. I get upset about fishes living in dirty water..	.55				
54. I would like to work for my environment to be clean.	.54				
53. Garbage on street attracts my notice.	.52				
50. I would like to grow plants.	.51				
7. Environmental pollution is dangerous to all living creatures.	.48				
55. I feel sorry when I see the wasted taps.	.46				
26. The garbage thrown away at school attracts my notice.	.41				

28. I use water economically.	.38				
38. Environmental pollution affects the habitats of some living things.	.325				
		37. I talk about current environmental problems with my friends.	.65		
		17. I know the plants in my environment.	.62		
		32. I watch documentaries about living creatures.	.56		
		23. I know where the recycling boxes are for used batteries.	.54		
		41. I know the animals in the environment I live.	.48		
		21. We do less harm to environment when we use public transport instead of cars.	.48		
		14. I feed street animals.	.47		
		19. We may have trouble finding clean drinking water in the future.	.46		
		22. I know the things that can be recycled in my environment.	.44		
		16. Random disposal of used batteries damages the environment.	.40		
				47. Damaging forests do not affect the natural life negatively.	.68
				59. I do not use the water economically.	.66
				43. The lights left open do not attract my attention.	.65
				27. I don't be upset about the pollution in my environment.	.61
				25. It is not my responsibility to protect the environment.	.54
				51. I do harm to animals.	.48

As a result of factor analysis, three subfactors as "Positive Environmental Behaviors", "Environmental Information and Awareness", "Negative Environmental Behaviors" were created. "Positive Environmental Behaviors" subfactor consists of 27 completely positive items, "Environmental Information and Awareness" subfactor consists of 10 completely positive items and "Negative Environmental Behaviors" subfactor consists of 6 completely positive items. Their item loads valued between .32 and .85.
In Table 8, eigenvalue and variance values that represented by scales are given. The eigenvalue of "Positive Environmental Behaviors" subfactor is 14.70, eigenvalue of "Environmental Information and Awareness" subfactor is 2.53 and "Negative Environmental Behaviors" subfactor's eigenvalue is 2.11. Total variance percentages were founded as 44.56. It can be said that the scale is consisted of three factors since it's variance rate is over the acceptable value of %41 (Kline, 1994).

Table 5. Eigenvalues and variances explained by the scale factors

Subscales	*Eigenvalues*	*Variance*
1. Positive Environmental Behaviors	14.70	34.19
2. Environmental Information and Awareness	2.53	5.47
3. Negative Environmental Behaviors	2.11	4.90
Total	19.34	44.56

Bogner and Wiseman (2006) and Costello and Osborne (2005) propose a confirmatory factor analysis to test the correctness of the model which resulted from the exploratory factor analysis. Table 9 shows the results of confirmatory factor analysis.

Table 6. Compliance parameters related to the confirmatory factor analysis model of the scale

Conformity Parameter	*Index*
GFI (Goodness of Fit Index)	0.65
AGFI (Adjusted Goodness of Fit Index)	0.62
RMSEA (Root Mean Square Error of Approximation)	0.089
Df	857
x^2	2120.64
(Chi-square) x^2/df	2,47

In Figure 1, the standard value diagram of the proposed model is presented:

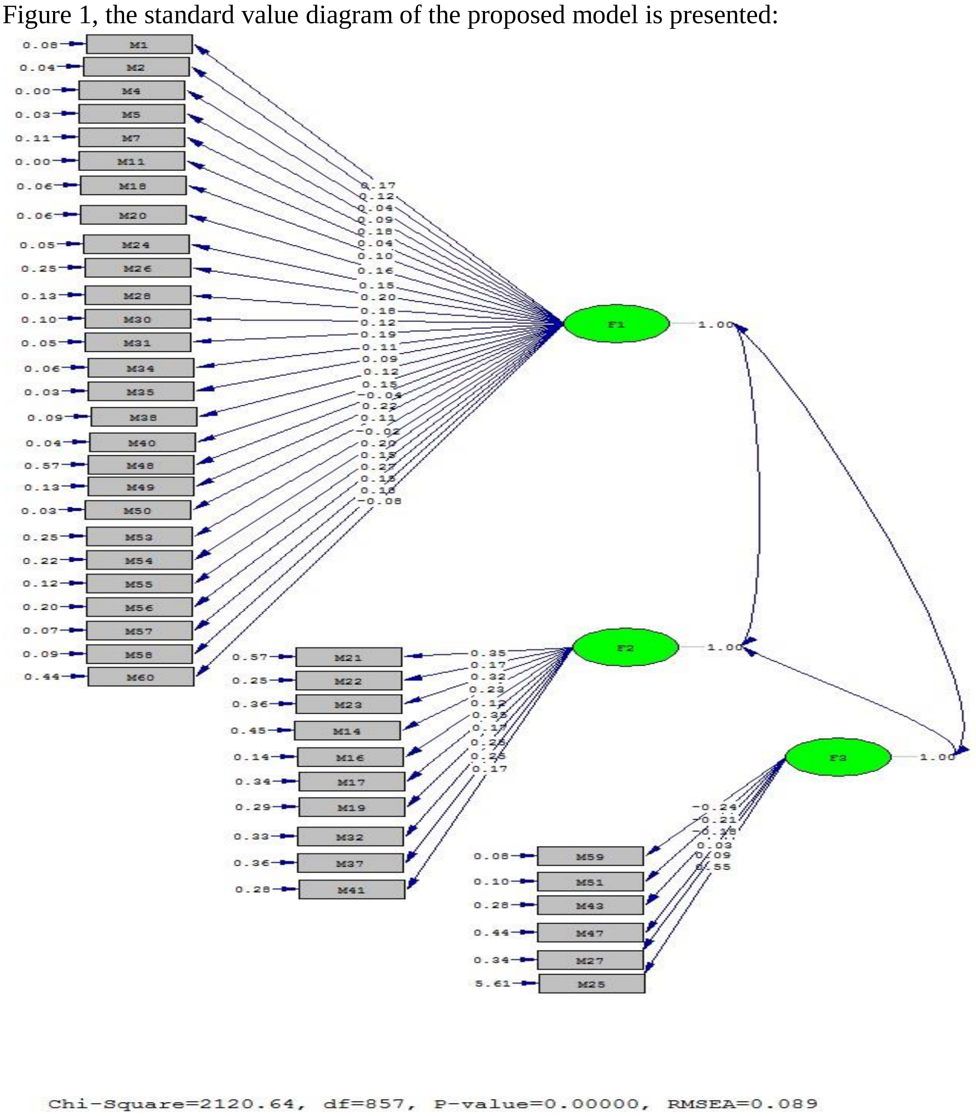

Figure 1. Standard value diagram related to the confirmatory factor analysis model

The results of confirmatory factor analysis and exploratory factor analysis were verified. x^2/df value was found significant. If x^2/df ratio is below 3, it is the perfect fit, whereas below 5 is satisfactory. In this case, x^2/df ratioof the scale is a perfect fit (Şimşek, 2007).

RMSEA is acceptable between .05 and .08 and it is regarded as perfect fit when the value is between .00 and 0.50 (Brown and Cudeck, 1993). According to these values, RMSEA value was considered acceptable. Pearson's product-moment correlation analysis was used. Correlations between subscale points of the scale are changed between 0.26 and 0.59 and statically significant. Table 7 shows the correlations between all subscales.

Table 7.Correlation coefficients between the subscales

Subscales	***1***	***2***	***3***
1. Positive Environmental Behaviors	-	0.59**	0.35**
2. Environmental Information and Awareness		-	0.26**
3. Negative Environmental Behaviors			-

** p<.01

Findings Related to the Reliability of the Scale For the reliability, Cronbach's Alpha coefficient was calculated. In Table 8, subfactors of scale and Cronbach's Alpha coefficient values of all are given.

Table 8. Cronbach's alpha coefficients of scale subscales

Subscales	***Alpha***
Positive Environmental Behaviors	0.94
Environmental Information and Awareness	0.75
Negative Environmental Behaviors	0.71
Total	0.93

Cronbach's Alpha coefficient was determined between 0.71-0.94, and 0.03 for all of the scale. These values indicate that the scale can measure consistently. According to Büyüköztürk (2004) reliability coefficients over 0.70 and above is acceptable, whereas Şencan (2005) stated that although this value is acceptable in scientific studies, interest and talent type of researches requires scales to have at least 0.85 reliability coefficient.

Discussion and Suggestions

As a result of this study, three point Likert scale consisting of 43 items, in order to measure the third grade students environmental attitudes, was developed. In that scale, "Positive Environmental Behaviors" subfactor consists of 27 items, "Environmental Information and Awareness" subfactor consists of 10 items and "Negative Environmental Behaviors" subfactor consists of 6 items. When examining the studies concerning environmental attitudes in literature, it is seen that these studies were performed mostly with the teacher candidates, high school students and middle school students (Alp, Ertepınar, Tekkaya and Yılmaz, 2006; Altınöz, 2010; Atasoy, 2005; Atasoy, 2012; Atasoy and Ertürk, 2008; Beklan Çetin, 2002; Erdoğan and Ok, 2008; Ergezin and Çetin Teke, 2013; Karataş, 2013; Okur and Yalçın Özdilek, 2012). It is seen that there is not much weight given to environmental education in literature for early ages. More importance should be given to environmental education in primary school. Moreover, it is seen that the studies concerning the environmental attitude (Alp, Ertepınar, Tekkaya and Yılmaz, 2006; Atasoy, 2005; Atasoy, 2012; Atasoy and Ertürk, 2008; Beklan Çetin, 2002; Erdoğan and Ok, 2008; Ergezin and Çetin Teke, 2013; Uzun and Sağlam, 2006) deal with the environmental attitude as different components (knowledge, behavior, attitude). Atasoy (2005) examined the knowledge and attitude of primary second grade studens. While there are differences of environment knowledge among 6^{th} and 8^{th} , 7^{th} and 8^{th} grade students, it is seen that there is a difference of environmental attitude among 6th and 8th grade students. Alp, Ertepinar, Tekkaya and Yilmaz (2006) found that primary school students' attitudes and knowledge towards the environment, class level and gender influence on their knowledge and attitudes, and the relationship between useful behaviors towards the environment and intentions, emotions, information and internal-external control focus. Kuhlemeier, Bergh and Lagerweij (1999) examined the relationship between environmental knowledge, environmental attitude and behavior in their studies. Uzun and Sağlam (2006) dealt with the "behavior" and "thought" of attitude's three dimensions, and left "emotion" dimension to their next study. Beklan Çetin (2002) examined environmental information, environmental attitudes and environmental behaviors. It was found that environmental knowledge has a significant influence on environmental attitudes.

In scale development studies, performing analysis as exploratory factor analysis with induction, confirmatory factor analysis with deductive contributes to the theoretical foundation to be steady (Okur and Yalçın-Özdilek, 2012). In this respect, besides the exploratory factor analysis in scale development studies, using other factor analyses in literature will contribute to studies to build on strong foundations. The environmental attitude scale developed for primary school students, was prepared to include cognition, perception and behavior dimensions of environmental attitudes of the third grade students. Moreover, while developing the scale, exploratory and confirmatory factor analyses were used. For that reason, scale development study is important.

Teachers can use the scale in their classrooms in order to determine the environmental attitudes of the students. With this developed scale, survey studies can be carried out in province, region or throughout Turkey. In surveys, joint studies can be carried out with the help of the academicians and form teachers in order to raise individuals who have positive attitude for environment, in schools and classes that the scale gives low results. The scale can be used by the teachers implementing educational programs and also by program developing experts in an attempt to determine the situation and the needs. Being individuals having positive attitudes towards the environment is a prior condition required for health of today's world and its continuity. It is significant to acquire this attitude at early ages. Changing the acquired wrong attitudes is harder than acquiring new attitudes. It is important to spend less energy and resources, and try to acquire environmental attitude at early ages so that nature gets least harm.

Note

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References

Acat, M. B., Tüken, G., &Karadağ, E. (2010). The scale of scientific epistemological beliefs: Adapting for Turkish culture, language validity & examination of factor structure. *Journal of Turkish Science Education*, 7(4), 67-94.

Alp, E., Ertepınar, H., Tekkaya, C. & Yılmaz. A. (2006). A study on Environment-Oriented Attitude and Knowledge of Primary School Students, *VII. National Congress on Education in Science and Mathematics, Gazi University, 07-09th September 2006, Abstracts Book*. pg 110.

Altınöz, N. (2010). Literacy Levels of Teacher Candidates of Science (unpublished post-graduate thesis). Sakarya University, Sakarya.

Atasoy, E. (2005). *Education for Environment:A Study on Environmental Attitude and Knowledge of Primary School Students* (unpublished doctoral thesis). Uludağ University, Bursa.

Atasoy, Ü. Ö. (2012). Acqusition level of STSE related to the topics of Primary School curriculum *and researching the attitudes of the students towards these topics.* (unpublished post-graduate thesis). Gazi University, Ankara.

Atasoy, E. & Ertürk, H.(2008). *A Field Study on The Environmental Attitude and Knowledge of Primary School Students. Erzincan Faculty of Education Periodical*, 10(1), 105-122.

Baloğlu, N., Karadağ, E. & Karaman, H. (2008). Strategical Planning Attitude Scale: Study of Exploratory and Confirmatory Factor Analyses. Educational Sciences on Theory and Practice 8 (2), 407-437

Beklan Çetin, O. (2002). *Environmental knowledge, attitude and behavior in Eskişehir.* (unpublished doctoral thesis). Middle East Technical University, Ankara.

Benli, N., Ay, Y. & Kahramanoğlu, R. (2011). *The effect of project based education on the attitudes of the students towards the environment in the teaching of sound, light, air, water and soil pollution.* 20th National Congress of Educational Sciences, 8-10 September 2011, Burdur.

Bogner, F. X. &Wiseman, M. (2006). Adolescent' attitudes towards nature and environment: quantifying the 2-MEV model. *TheEnvironmentalist,* 26, 247-254.

Brown, M.,&Cudeck, R. (1993). *EQS structural equations program manual.* Multivariate Software Inc., Los Angeles.

Büyüköztürk, Ş. (2004). *Data analysis handbook for social sciences. Statistics, research design, SPSS applications and comments.* Ankara: Pegem Academy.

Chapman, D. &Sharma, K. (2001). Environmental attitudes and behavior of primary and secondary students in asiancities: an overwiev strategy for implementing an eco-schools programme, *TheEnvironmentalist,* 21, 265-272. doi: 10.1023/A:1012996016601

Costello, A. B.&Osborne, J. W. (2005). Best practices in exploratory factor analysis: four recommendations forgetting the most from your analysis. *Practical Assessment Research& Evaluation*, 10 (7), 1-9.

Demir, Z. M. (2016). Environmental attitude scale developing study for primary school students. (unpublished post-graduate thesis). Eskişehir Osmangazi University, Eskişehir.

Erdoğan, M. & Ok, A. (2008). *Environmental literacy assessment of Turkish children: the effects of background variables.* The WCCI 13th World Conference in Education, September 02-06, Antalya, Turkey.

Ergezin, Ö. U. & Çetin Teke, E. (2013). A study on developing an environmental behavior and attitude scale for university students. Journal of Educational and Instructional Studies in the World. 3(2), 49-56.

Erten, S. (2004). What is environmental education and consciousness, How should environmental education be? *Environment and People Journal, Ministry of Environment and Forestry Media Organ, Number 65/66.*

Gökçe, N., Kaya, E., Aktay, S. & Özden, M. (2007). Attitudes of Primary School Students towards Environment. *Primary Education Newswire,* 6(3), 452-468.

Karataş, A. (2013). The role of environmental education concerning the environmental consciousness and Niğde University Faculty of Education. (unpublished doctoral thesis). Ankara University, Ankara.

Keleş, R. & Hamamcı, C. (2005). Environmental Policy (5th Print). Ankara: İmge Bookstore.

Kline, P. (1994). *An easy guide to factor analysis*. New York, NY: Routledge.

Kuhlemeier, H.,Bergh, H. &Lagerweij, N. (1999). Environmental knowledge, attitudes and behavior in Dutch secondary education, Journal of Environmental Education, 30 (2). 4-14.

MEB (Ministry of National Education) (2013). Primary Education Institutions (primary and middle schools) science lesson (3, 4, 5, 6, 7, 8th grades) education programs. Ankara: MEB Publications

Okur, E. & Yalçın-Özdilek, Ş. (2012). Environmental attitude scale developed with Structural Equation Modelling. *Primary Education Online, 11*(1), 85-94.

Şimşek, Ö. F. (2007). Introduction to structural equation modeling. (basic principles and LISREL applications). Ankara: Ekinoks.

Uzun, N.,&Sağlam, N. (2006). Developing environmental attitude scale for middle school studens and the validity. *Hacettepe University Faculty of Education Periodical* ,30, 240-250.

Yaşaroğlu, C. (2012). Environmental attitude and behavior assessment of primary school students. (unpublished doctoral thesis). İnönü University, Malatya.

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Appendix

Environmental Attitude Scale

Note: The original scale has been developed in Turkish. It is necessary to ensure the language validity for using in different languages.

A. Positive Environmental Behaviors	***Agree***	***Partially Agree***	***Disagree***
We should protect the nature.			
I don't do harm to animals.			
I do not damage trees.			
I turn off the lights that are left on.			
Clean air is important for our health.			
Clean environment makes me happy.			
When I see a flowing faucet, I close it.			
I do not throw garbage on street.			
All living creatures need a clean world.			
Feeding animals makes me happy.			
I do not harm the plants.			
Trees and flowers need clean water.			
I throw waste pills on waste battery box.			
Recycling is important.			
I do my part regarding the cleanliness of our class.			
It is important for our future to have an economical use of resources (water, electricity, natural gas, etc.).			
I love animals.			
Animal extinction makes me sad.			
I get upset about fishes living in dirty water.			
I would like to work for my environment to be clean.			
Garbage on street attracts my notice.			
I would like to grow plants.			
Environmental pollution is dangerous to all living creatures.			
I feel sorry when I see the wasted taps.			
The garbage thrown away at school attracts my notice.			
I use water economically.			
Environmental pollution affects the habitats of some living things.			
B. Environmental Knowledge and Awareness	***Agree***	***Partially Agree***	***Disagree***
I talk about current environmental problems with my friends.			
I know the plants in my environment.			
I watch documentaries about living creatures.			
I know where the recycling boxes are for used batteries.			
I know the animals in the environment I live.			
We do less harm to environment when we use public transport instead of cars.			

I feed street animals.			
We may have trouble finding clean drinking water in the future.			
I know the things that can be recycled in my environment.			
Random disposal of used batteries damages the environment.			
C. Negative Environmental Behaviors	***Agree***	***Partially Agree***	***Disagree***
Damaging forests do not affect the natural life negatively.			
I do not use the water economically.			
The lights left open do not attract my attention			
I don’t be upset about the pollution in my environment.			
It is not my responsibility to protect the environment.			
I do harm to animals.			

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Evaluating the Gifted Students' Understanding Related to Plasma State Using Plasma Experimental System and Two-Tier Diagnostic Test

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Abstract

The purpose of this study was to investigate the effectiveness of the experimental system design related to plasma state on the gifted students' understanding on the subject of the plasma state. To test the research hypothesis, one group pretest-posttest research model was carried out with 18 eighth-grade (4 girls and 14 boys) gifted students in mathematics and science, attending to a university-based after school program for gifted students. A two-tier achievement test (Plasma Achievement Test-PAT) consisting of 10 items used as a pretest and posttest. First tier of the test consists of multiple-choice items and the second tier consists of open-ended items. Students were asked to find the correct answer in the first tier and write the reasons (justifications) for their answers in the second tier. Pretest and posttest mean scores of first and second tier scores were compared with statistical analyzes. Also the students' justifications for the second tier of the test was used to make content analyzes. From pretest to posttest an increase was found in open-ended tier scores. The difference between pretest and posttest wasn't statistically significant for multiple-choice tier scores. From the findings it can be concluded that the experiment system was effective on the gifted middle school students' understanding on the subject of the plasma state.

Introduction

The success in the physics courses depends on most variables such as teacher, the content of the course, availability of the devices for the laboratory experiments, an applicable schedule and open learning philosophy to meet the requirements of the students, making critical efforts to achieve the learning goals. The researches show that the experiments play an effective role in understanding the physical phenomena in physics and in our world (Psillos & Niedderer, 2002). The learning strategies containing the experiments ensure that the students associate the theory to the practice and gain an ability to do experiments and to think scientifically and aim their cognitive developments (Hofstein & Lunetta, 2004). The students must take an active role in all stages of the process to ensure that the experiments are considered as most important training tools in the physics course especially to teach difficult or abstract concepts. Any tools and equipment required by the experiments that are expected to be conducted in the scope of the physics course curriculum are in general accessible easily. But, if there are any technical or physical limitations, it is proposed that different techniques such as the demonstration experiments or simulations are used. It is highly difficult to realize the experiments related to plasma state of the matter, which constitutes the subject of this study, in a classroom environment due to the technical limitations and working at a high voltage.

The plasma defined the first time by Irwin Langmuir in as an ionized gas containing a free particle in 1928 constitutes more than 99% of the universe (Langmuir, 1928). Examples of the plasmas in the universe include sun, stars, solar winds, supernovas and nebulas. Examples of the plasmas in our earth include polar lights (Aurora), lightning, flash, fire, ionospheric region of the earth, magma layer of the earth and Van Allen belts. Moreover, the plasmas are keys to understanding the behaviors of all structures from the plasmas filling the interstellar environment to the extra galactic jets dispersed from the disks encircling the black holes.

Also, as stated in the reports of the American National Council on Plasma Science, the plasmas plays an important role in the development of most of today's advanced technologies (National Research Council [NRC], 2007). Although they are not known very well by the public, the plasmas are used in most of the high technological devices. One of the basic applications of the plasma technology relates to the micro and nano technologies. More than 50% of the equipment consists of the plasma reactors in a clean manufacturing room, where the integrated circuits used in the memories or microprocessors that take up a lot of room in the daily are manufactured. The plasma technologies are also used in many different applications in the chemical industry (e.g. gas mitigation, gas production, etc.), medical industry (e.g. plasma sterilization, plasma treatment, etc.), material industry (etc. coating, functionalization, etc.) and other most industries (Liebermann and Lichtenberg, 1994). Furthermore, examples of the plasmas produced in vitro include the neon advertisement lamps brought by the modern technology, Xenon headlights of vehicles and sodium vapor lamps (Contemporary Physics Education Project [CPEP], 2014; Elizer & Eliezer, 2001; Eskisehir Osmangazi University [ESOGU], 2014; Grill, 1993). Although the plasma application fields are highly broad, it is essential that the basics of the plasma physics are taught by the new generation scientists early as possible (O'Brien, Zhu, & Lopez, 2011). Recently, any various training practices led by universities for this purpose stand out. For example, the education programs and cooperation projects between the plasma laboratories such as the Princeton University, Plasma Physics Laboratory (PPPL) and Tokyo University, Institute of Frontier Sciences (Graduate School of Frontier Sciences) are started, and the scientists, who work on plasma, work with graduate and postgraduate students to teach the main properties of plasma and plasma technologies (Tillocher et al., 2015; Prager & Ono, 2014). It is seen that, although they are included in the high school curriculum, such education practices are limited to high school students. A limited number of students, which meet a high criteria, are admitted to a few plasma education programs that may also be utilized by high school students. For example, only the high school students from the New Jersey region admitted to the Saint Peter’s University, Center of Microplasma Science Technology (CMST), and these students then describe the plasma subject to their friends in their schools (CMST, 2016).

Plasma state, which takes up a large place both in the universe, where we live, and in our daily life, takes a place in the physics course curriculum of the secondary education of the Ministry of National Education in our country. It is aimed that the students adopt the principle “*describing the general properties of the plasma by giving examples*” on the plasma subject as the final subject the “Matter and Its Properties” unit, which is the second unit of the ninth-grade curriculum, and for which 12 course hours. Expression of the subject must be supported by the experiments to ensure that the students may gain any achievements on plasma like almost all physics subjects. The literature review shows that the experiments concerning plasma state are limited only to the plasma sphere, and knowledge and experience of the student on the plasma phenomena are highly limited for secondary education students.

We realized any studies, both with the secondary school students and with candidate science teachers by using the experiment system as a demonstration experiment concerning plasma state (Korkmaz, 2015; Korkmaz, Aybek, & Pat, 2015). These studies show that the basic properties of the plasma cannot be perceived very easily and the designed experiment system is effective in understanding the plasma subject. In these studies, that we also support with the discharge tube simulation as a plasma environment, it is determined that the students must understand and have an ability to apply dynamic, electrics, magnetism and modern atom theory for them to able to deceive the plasma and its basic properties. Such acquisitions are possible for secondary education students, for whom the physics course curriculum of the secondary education in Turkey, only, when they come to the twelfth-grade level. To the best of our knowledge, previously, no one has reported such a study included demonstration experiments concerning plasma state which is a state that exists widely in the universe and that is used to produce new products and generate energy today, conducted with gifted students. Therefore, the purpose of this study was to investigate the effectiveness of the experimental system design related to plasma state on the gifted students’ understanding on the subject of the plasma state.

Method

Study Group

The study group of the study 18 eighth-grade students (7 girls and 11 boys), who continue the Education Program for Gifted Students (EPGS) of the Anadolu University. The EPGS is an afterschool weekend program designed to serve the gifted middle school students in mathematics and science fields. The students are admitted by the identification process, where the specific identification tools for mathematics and science fields, are used (Mathematical Ability Test [Sak, 2009] and Scientific Productivity Test [Ayas & Sak, 2014]). An academically accelerated and enriched curriculum in science and mathematics is submitted to the students, who are admitted to the program (Sak, 2013). Therefore, the EPGS students have reached their knowledge level on any subjects such as dynamics, electrics and modern atomic theory, which are in a nature of prerequisite to understand the plasma subject, in 8th grade of the primary school. In this respect, the eighth-grade EPGS students, who are enrolled in the program in 6th grade as a result of the identification process, and continues the third year of the program, are included in our research.

Data Collection Tools

Plasma Achievement Test

The Plasma Achievement Test (PAT) developed in 2015 by the Korkmaz (2015) for the purpose of collecting data (Korkmaz, 2015; Korkmaz, Aybek, & Pat, 2015) is used as a pretest and posttest in the study. PAT is a test which consisting of 10 multiple-choice and 10 open-ended items to purpose of determining the knowledge level of the students on plasma. With the open-ended items in the test, the students are required to justify their answers to the multiple-choice items.

In the developing process of PAT a 20 item pilot test form was prepared. The pilot test was presented to two measurement and evaluation specialists, two physics teachers, one physical science specialist and one science teaching-specialist for expert opinion. In accordance with the opinions of the experts, necessary corrections were made in the test items and the final form of the test was given. Item analysis and reliability study of the PAT were carried out with 80 students studying in the two different high schools in Eskişehir in the 2014-2015 academic years. Item difficulty and item discrimination indices were calculated. The most appropriate 10 items were selected according to the item analysis results. The detailed validity and reliability study of PAT can be found in the Korkmaz (2015).

The maximum score that can be taken each tier was 100. Each open-ended item scored polytomously between 1-10 with a rubric developed to grading open-ended items, and each multiple-choice item is scored dichotomously as 0 or 10. Then, students’ test scores for each tier calculated separately by summarizing the item-scores.

In the scope of this study, PAT is applied to the eighth-grade EPGS students, and the reliability coefficient is calculated as .69 according to the split-half method for this group. It is expected that the reliability coefficient is higher in the achievement tests, whereas the students in the study group are selected according to the same identification test, which means the group was very homogenous, may be caused that the reliability coefficient is calculated lower than the expected (Turgut & Baykul, 2010).

Process

The study is conducted in the scope of the EPGS science course. The plasma achievement test is applied primarily to the study group as a pretest. A plasma demonstration experiment supported by the simulation is conducted one week after the plasma achievement test is applied.

The discharge tubes filled with the low pressure and various gasses (Ar, Neon, etc.) are used in the experiment system. The gas atoms are transformed to plasma state by using the low frequency (10 kHz) power supply and electrodeless discharge method (Korkmaz, 2015). The first phase of plasma state is the ionization of atoms. The ratio of the number of particles ionized in the tube to total number of particles is between 0.1% and 1%. The number of electrons is equal to the number of ions. Upon initiation of ionization, ions and electrons are forced to collide with non-ionized gas atoms and with each other. Electricity and heat conduction within the plasma are provided by electron due to their high speeds. Masses of the electrons with a high energy are highly less that the ions and ionized particles within the plasma. Because pressure of a gas with plasma generated is low, electrons cannot collide many times with particles having masses larger than electrons, and therefore cannot transfer energy to these particles. Therefore, the kinetic energies, thus temperatures of the electrons in the low pressure plasmas are always larger than the particles having larger masses than the electrons. As known, the kinetic energies of the particles in the microscopic medium are perceived as a temperature in the macroscopic medium. Because the number of electrons is less than the total number of particles; energies, namely temperatures of ions and neutral atoms are highly low, the temperature of the medium never rises at a sensible degree. In the literature, this method is called *cold plasma*.

The plasma generation method is explained during the demonstration experiment, and any differences between the plasma obtained from the experimental system and the plasmas observed in nature are examined. Upon the demonstration experiment, *Neon Lights & Other Discharge Lamps* simulation is monitored (Phet, 2014). The achievement test is applied again immediately after the demonstration experiment.
The pretest and posttest papers of the students are scored by two independent scorers, and in cases of indecision, a mutual decision is made and the papers are scored by a consensus way.

Data Analysis

The answers of the students to the multiple-choice and open-ended items on the plasma achievement test are reviewed descriptively. The correct answers of the students in the multiple-choice items are multiplied by 10 to get a score range between 0 to 100. Thus, it is ensured that they may be compared to the open-ended items.
Then, pretest and posttest scores are compared as follows:

1. Pretest multiple-choice scores and pretest open-ended scores;
2. Posttest multiple-choice scores and posttest open-ended scores;
3. Pretest multiple-choice scores and posttest multiple-choice scores; and
4. Pretest open-ended scores and posttest open-ended scores.

Because the research group consists of 18 students, a non-parametric Wilcoxon-Signed Rank Test is used for the paired comparisons. To interpret whether the test result is significant or not, the determined significance level .05 is divided by the number of comparisons (4 comparisons) by making the Bonferonni adjustment. Therefore, it is accepted that α is equal to .0125, and the significance of the statistical test results are interpreted according to this value.

Findings

Distribution of correct, wrong and empty answers to the multiple-choice items in the pretest and posttest is given in Table 1:

Table 1. Variation of the correct, wrong and empty answers to the multiple-choice items

	Items									
Variations*	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
TT	17	6	11	12	3	1	14	13	12	7
TF		4		2		3	1		2	4
FT			4	2	10		2	4	2	1
FF	1	6		1	5	14		1	1	4
ET			3				1			
TE				1					1	
EE										1
EF		1								1
FE		1								

*TT: Correct in the pretest and correct on the posttest; TF: Correct in the pretest and wrong on the posttest; FT: Wrong in the pretest and correct on the posttest; FF: Wrong in the pretest and wrong on the posttest; ET: Empty in the pretest and correct on the posttest; TE: Correct in the pretest and empty on the posttest; EE: Empty in the pretest and empty on the posttest; EF: Empty in the pretest and wrong on the posttest; FE: Wrong in the pretest and wrong on the posttest.

As reviewed in Table 1, it is seen that, although some of the students give correct answers to items 2, 4, 6, 9 and 10 in the pretest, they give wrong answers in the posttest, and give wrong answers to items 2, 5, 6 and 10 in both pretest and posttest. When the justifications of the students, who give wrong answers, are examined, it is seen that the students state that plasma never transmits heat. During the demonstration experiment, the students are allowed to touch the discharge tubes as a media created by plasma. The students may interpret that, the plasma samples used in the demonstration are not hot, plasma never transmits heat. Another reason is that students may have previous knowledge. In both cases, *since the fluorescent lamps give light, the plasmas conduct electricity. Fluorescent lamps do not generate too much heat. The polar lights are formed by magnetism.* The student's previous knowledge about fluorescent tubes and polar lights lead him/her to the wrong answer. The similar situation is also observed in a plasma globe.

Another finding to be considered in Table 1 is that 14 students give wrong answers to 6th item in both pretest and posttest. When the answers of those 14 students are checked, it is observed that 12 and 14 students selected the *option A* (distractor) respectively in the pretest and posttest. Probably the cause of this situation is that the distractor is very strong. To create a plasma state in the experimental setup, first step primarily includes ionization of gas in the experiment tubes. Ions and electrons, which increase suddenly within the tube as initialization of ionization, are forced collide with non-ionized atoms and with each other within the tube due to uneven electrical field. As a result of collisions, excitations and ionizations begin in gas atoms. After the excited atoms emit photons to return to the base position, radiation is observed within the tube. Therefore, plasma state is a situation, when the ionized atoms, electrons, exited atoms, photons and neutral atoms exist together. In option A of 6th question, plasma is stated as "*it is an exited gas state of the matter*". However, when the simulation that is shown to the students is reviewed, it is observed that the demonstration in the simulation may cause a misconception in the students, because atoms are excited as a result of an electron bombardment in lieu of ionization. Therefore, the students may think that plasma state is an excited state of atoms by being under the influence of the simulation, and thus select the option A which is a strong distractor. The answer *"...plasma is an excited gas state, it emerges as a result of an electron bombardment."* given by a student to the respective open-ended item confirm this opinion. The statements of the students that "*it is an excited gas*" or "*it happens as a result of excitation of gases*" are also not deemed correct.

Distribution of numbers of the students, who leave unanswered and give wrong answers to the open-ended items (0 justification score) by pretest and posttest is given in Table 2.

Table 2. The number of the students, who leave empty and give wrong answers to the justification items in the pretest and posttest

Item	Empty		Wrong	
	Pretest	Posttest	Pretest	Posttest
1	0	0	1	1
2	4	2	7	2
3	9	3	6	3
4	5	3	3	0
5	7	4	9	7
6	3	2	13	14
7	5	4	10	6
8	3	2	3	0
9	5	4	6	1
10	5	3	12	8
Average	4.6	2.7	6.7	4.2

In Table 2, it is seen that number of students who give empty and wrong answers were reduced compared to the pretest.

The pretest and posttest scores of the students for the multiple-choice and open-ended items on the Plasma Achievement test are given in Table 3.

Table 3. The descriptive findings for PBT pretest and posttest scores

		Minimum	Maximum	Mean	SD
Multiple-choice	Pretest	40.00	80.00	63.38	13.34
	Posttest	40.00	80.00	67.77	11.14
Open-ended (Justification)	Pretest	10.00	34.00	20.38	7.55
	Posttest	16.00	68.00	37.83	16.82

In Table 3, it is seen that the pretest score average is 63.38 and the posttest score average is 67.77 for the multiple-choice items. Although an increase in the scores of the students is observed in the posttest, it is seen that the standard deviation of the group also reduces a little bit. When the scores of the open-ended items are reviewed, it is seen that the mean score of the students increased by approximately 17.5 points in the posttest. Standard deviation also has increased in the posttest. The cause of this increase in the standard deviation may be the facts that number of the students, who never state any justification in the pretest, are high and the pretest justification scores were low.

To determine whether there is a significant difference between pretest multiple-choice and open-ended scores and between the posttest multiple-choice and open-ended scores or not, the Wilcoxon-Signed Rank Test is used and the test results are given in Table 4.

Table 4. The results of the wilcoxon-signed rank test for the pretest multiple-choice – pretest open-ended and posttest multiple-choice – posttest open-ended items

			Mean Rank		Sum of Ranks			
	N	Median	Negative	Positive	Negative	Positive	Z	p
Pretest MC	18	65	9.50[1]	.00[2]	171.00[1]	.00[2]	-3.725	.000
Pretest OE	18	18						
Posttest MC	18	70	9.50[1]	.00[2]	171.00[1]	.00[2]	-3.724	.000
Posttest OE	18	36						

[1]N = 18; [2]N = 0; MC: Multiple-choice items; OE: Open-ended items.

It is determined that a significant difference between the pretest multiple-choice and open-ended mean scores in favor of the multiple-choice items (Z = -3.725, p < .0125). When the students' answers are examined, it is seen that the students who give correct answers to the multiple-choice items in the pre-test, cannot justify their answers. According to the Table 4, there is also a significant difference between the posttest multiple-choice and open-ended mean scores in favor of the multiple-choice items (Z = -3.724, p < .0125). Namely, the students give correct answers to the multiple-choice items, but cannot justify their answers in the same manner.

Wilcoxon-Signed Rank Test conducted to determine whether there is any significant difference between the pretest and posttest multiple-choice scores and between pretest and posttest open-ended scores. The results of the Wilcoxon signed rank test can be found in Table 5.

Table 5. Wilcoxon-signed rank test results for pretest – posttest multiple-choice and open-ended scores

			Mean Rank		Sum of Ranks			
	N	Median	Negative	Positive	Negative	Positive	Z	p
Pretest MC	18	65	6.83[1]	5.69[2]	20.50[1]	45.50[2]	-1.137	.256
Posttest MC	18	70						
Pretest OE	18	18	10.50[3]	9.44[4]	10.50[3]	160.50[4]	-3.268	.001
Posttest OE	18	36						

[1]N = 3; [2]N = 8; [3]N = 1; [4]N = 17; MC: Multiple-choice questions; OE: Open-ended items.

According to the Wilcoxon-Signed Rank Test, there is no significant difference between pretest and posttest multiple-choice scores (Z = -1.137, p > .0125). However, that there is a significant difference between pretest and posttest scores for open-ended items (Z = -3.268, p < .0125). Accordingly, it may be said that the students may justify the questions asked to them better in the posttest.

Conclusion

In this study that the plasma demonstration experiment is presented to the students, who continue to the EPGS, and the change in the knowledge levels of the students on plasma is examined. There is no significant increase is found from the pretest to the posttest according to multiple-choice items. In the open-ended tier, where the students justify their answers, it is determined that the students had given better justifications in the posttest, and accordingly, there is a significant increase in the mean score. In this scope, it may be said that the use of the experimental setup increases the knowledge level of the students significantly. Also in similar researches (Korkmaz, 2015; Korkmaz, Aybek, & Pat, 2015), the same finding is reported and this shows the significance of the experiment setup in learning the concepts especially such as plasma in the science education. Furthermore, it may be thought that use of the open-ended tests or two-tier tests such as PBT is more useful in the measurement and evaluation stages in the science course.

When the results of this study are compared to the results of the past research, where the same plasma achievement test and experiment system are used, and which was conducted together with the 9^{th} grade students (Korkmaz, 2015), it is remarkable that the posttest mean score of the 8^{th} grade students, who continue to the EPGS program, is 67.77, while the multiple-choice tier mean score of the 9^{th} grade students were 42.10 in the posttest. A similar situation is also observed in the mean scores of the open-ended tier. It is found that the posttest mean score of the 9^{th} grade students is 14.69, and the posttest mean score of the 8^{th} grade students, who continue to the EPGS program, is 37.83. This may be arisen from the properties of the students, who continue to the EPGS program, and contents of the program, because an accelerated curriculum is submitted to the gifted students in the EPGS science and mathematics fields (Sak, 2013). In this scope, it may be said that that the preliminary knowledge level of the EPGS students is higher than one of the 9th grade students. Hence, when the pretest multiple-choice and open-ended tier scores of both student groups are compared, it is seen that the mean score of the EPGS students (63.38 in the multiple-choice tier, and 20.38 in the open-ended tier) is higher than the ones of the 9th grade students (25.4 in the multiple-choice tier, and 10.46 in the open-ended tier (Korkmaz, 2015)).

When the answers of the students to each question are reviewed, it is observed that they come to an incorrect conclusion, especially with the items related heat conduction of plasma and submit the experiment setup as a proof in their justifications. For example, a student states his/her justification that "*If it transmits heat well, no energy saving may be obtained in fluorescent lamps, and the fluorescent lamps are more hot that the filament lamps. Furthermore, no heat conduction happens in our hands in the experimental setup and plasma globe, once we conduct."* for the second question. If the students reached such a conclusion as a result of the experiment, may be its main cause includes a plasma generation method in this system. Since the low pressure discharge tubes are used in the experiment system, the temperature of the medium never rises at a sensible degree. It is observed that the student shows, an excessive interest to the experimental setup and it may be supposed that the students, who contact the discharge tubes, concluded that the tubes never transmit heat, because the discharge tubes are not hot.

It is remarkable that the majority of the students give wrong answers at item 6 in both Pretest and Posttest. It is observed that the students tend to the wrong option A (distractor) in this item. The simulation shows the excitation of atoms as a result of an electron bombardment, not ionization stage. Therefore, maybe the students thought that plasma state is an excited state of atoms of being under the influence of the simulation, and thus chosen the option A.

Recommendations

As if a mediocre reliability coefficient obtained in the plasma achievement test used in the research may be arisen from homogeneity and small size of the group. Yet, the development of a new plasma achievement test shall be useful for the researchers, who intend to work on a similar subject. Furthermore, standardization of this test is useful to compare the results that may be obtained in future studies.

It is supposed that the plasma generation method used in the experimental system creates a perception in the students that plasma never transmits heat. To determine whether this perception of the students is caused really by the experiment setup or not, a qualitative research may be conducted together with up the students. This shall be a guide for both development of the experimental system and future developments of new achievement tests based on plasma state subject.

It is understood that the demonstration of the simulation after the experiment could cause a misconception in the students from this study group. Therefore, it can be examined in future studies whether the simulation causes any other misconceptions in similar groups. Furthermore, future researches could be conducted on with the updated simulation in accordance with the findings of this study.

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References

Ayas, M. B., & Sak, U. (2014). Objective measure of scientific creativity: Psychometric validity of the Creative Scientific Ability Test. *Thinking Skills and Creativity*. *13*, 195-205.

Center for Microplasma Science and Technology. (2016). *Education and research*. It was accessed on 05.04.2016 at https://www.saintpeters.edu/cmst/93-2/

Contemporary Physics Education Project [CPEP]. (2014). http://www.cpepweb.org/

Elizer, S., Eliezer, Y. (2001). *The Fourth State of Matter an Introduction to Plasma Science*. İOP publishing.
Eskisehir Osmangazi University [ESOGU]. (2014). *Plasma science and technologies lab home page*. http://esoguplazma.ogu.edu.tr
Grill, A. (1994). *Cold Plasma in Materials Technology: from fundamentals to applications.* New York: IEEE Publishing.
Hofstein A., & Lunetta V.N. (2004). The Laboratory in science education: Foundations for thetwenty-First Century. *Science Education*. 88 (1). 28-54
Korkmaz, S.D. (2015). A new experimental system design related to the plasma state. *Educational Research and Reviews.* 10(17), 2501-2511.DOI: 10.5897/ERR2015.2452
Korkmaz, S. D., Aybek, E.C. & Pat, S. (2015). The Effect of New Experimental System Design Related to the Plasma State on Achievement of Candidate Elementary Science Teachers. *Universal Journal of Educational Research.* 3(10): 735-741. DOI: 10.13189/ujer.2015.031012
Langmuir, I. (1928). Oscillations in Ionized Gases. *Proc. Nat. Acad. Sci.* 14, 627.
Liebermann, M. A., & Lichtenberg A. J. (1994). *Principles of plasma discharges and materials processing*. John Wiley and sons Inc.
National Research Council [NRC] (2007). *Plasma Science: Advancing Knowledge in the National Interest*. Washington, DC: National Academy Press.
O'Brien, D.A., Zhu, W. & Lopez, J.L. (2011). Student Experiences with Plasma Phenomena. *IEEE Transactions on Plasma Sciences*, Vol. 39, No. 11, 2584-2585.
Prager, S. & Ono Y. (2014). *A Tokyo / Princeton Educational Partnership in Plasma Physics*. http://www.princeton.edu/international/doc/Prager_Ono-2014_15-PU_UTokyo-Proposal-PR.pdf
Psillos, D., & Niedderer, H. (2002). *Issues and Questions Regarding the effectiveness of Labwork in Teaching and Learning in the Science Laboratory*, D. Psillos and H. Niedderer, Eds. Dordrecht: Kluwer, pp. 21-30.
Sak, U. (2008). Test of the three-mathematical minds (M3) for the identification of mathematically gifted students. *Roeper Review*. *31*(1), 53-67.
Sak, U. (2013). *Gifted people: Their properties, identification and education.* Ankara: Vize Publishing House.
Tillocher, T., Aubry, O., Boufendi, L., Pichard C., Lefaucheux, P. & Dussart, R. (2015). *Engineering and research education in Plasma technology*. 43rd Annual SEFI Conference June 29 - July 2, 2015 Orléans, France.
Turgut, M.F., & Baykul, Y. (2010). *Measurement and Evaluation in Education.* Ankara: Pegem Akademi.

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The Effect of Using Virtual Laboratory on Grade 10 Students' Conceptual Understanding and their Attitudes towards Physics

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Abstract

This study investigated the effect of using (VL) on grade 10 students' conceptual understanding of the direct current electric circuit and their attitudes towards physics. The research used a quantitative experimental approach. The sample of the study was formed of 50 students of the tenth grade, aged 14 to 16 years old, of an official secondary school in Mount Lebanon. Participants were randomly assigned into two groups of 25 students each. The experimental group was taught using VL, where experimental activities were conducted through Circuit Construction Kit developed by the PhET simulations. However, the control group was taught through interactive demonstrations using real laboratory equipment. Both groups were pre and post-tested by means of two instruments: "Determining and Interpreting Resistive Electric current Concepts test" (DIRECT) and "Physics Attitude Scale" (PAS). The data analysis of the DIRECT test scores showed that, after 10 weeks, the conceptual understanding of the direct current electric circuit had markedly improved in both groups. However, the mean score of the experimental group was significantly higher than that of the control group. On the other hand, there was no significant difference in students' attitudes towards physics between the two groups.

Introduction

Physics is the science of experimental evidence, criticism, and rational discussion where knowledge and understanding of its concepts depends on the perception of the physical phenomena. Among many researchers in Physics education, Halloun and Hestenes (1985) and McDermott (2001) have shown the ineffectiveness of traditional instructional methods, and shed the light on the lack of understanding science content and processes when students were subjected to conventional teaching of lecture and demonstrations. Resorting to laboratory experiments is one of the main efficient means to make the comprehension of difficult theories simpler and clearer (McDermott, 2001). Meaningful learning, can be achieved when laboratory activities become an integral part of the science curriculum (NSTA, 2007). According to Onyesolu (2009) learning science has been restrained by the deficiency or inadequacy of laboratory equipment in schools. From this standpoint, there is a need for a new unconventional alternative laboratory environment where students can conduct the different required experiments at any time and in safe conditions. One of the solutions that may help in overcoming these obstacles can be the use of virtual laboratories. According to Halloun (1996) resorting to progressively sophisticated software endorses a constructivist approach to learning. Pedagogical principles of inquiry-based learning, exploration, and genuine activities in science support the use of technology in an attempt to provide basic instruction mainly due to the increasing importance of enhancing students' motivation and engagement in science instruction. Virtual laboratories offer students the opportunity to achieve the learning objectives, while overcoming the aforementioned constraints. Virtual laboratories have therefore arisen in schools and universities as being powerful efficient tools that may offer wide-range alternatives as learning environments that attract students' interests and may be a great incentive to them (Onyesolu, 2009).

In Lebanon, the Center for Educational Research and Development (CERD), established and categorized competencies that must be developed in science into four domains: Using acquired knowledge, practicing scientific reasoning, mastering experimental techniques, and mastering communication techniques (CERD, 1995). The experimental techniques depend extremely on laboratory work and experiments that unfortunately are not used in most Lebanese schools, particularly the public ones, due to a number of barriers (Zgheib, 2013). As a physics teacher for secondary classes in Lebanon since 2008, the first researcher has tried to resort to laboratory experiments in her teaching approach. However, she was able to realize only few experiments due to the lack of laboratory equipment on one side and the inexpertness of students on the other. Some of the main problems she has encountered during her experience in the secondary teaching were: The insufficiency or absence of laboratory facilities; the time factor in planning and performing experiments; and the inability to keep tracking of students' performance during the activities. Based on this approach, and in order to solve the problems faced, experiments were conducted by replacing the real lab with a virtual lab. According to Aldrich (2005) virtual labs help students conduct experiments and explore phenomena that cannot be conducted in traditional laboratory surroundings, either because it is not feasible or because of the unavailability of essential laboratory equipment.

Virtual Laboratories

Virtual laboratories provide simulated versions of traditional laboratories referring to a learner-centered approach in which the learner is provided with objects that are virtual representations of real objects used in traditional laboratories. Virtual laboratories may contribute to teaching and learning processes by giving students the opportunity to learn by doing, providing them with intriguing and enjoyable activities urging them to discover, and guaranteeing an active classroom interaction by means of discussions and debates (Lkhagva, Ulambayar, & Enkhtsetseg, 2012). The use of virtual laboratories can offer students the opportunity to investigate situations that cannot be tested in real time by speeding up or slowing down time (Aldrich, 2005). They are also beneficial to study advanced concepts such as relativity and experimentation that would not be studied or realized in traditional laboratory settings (Aldrich, 2005, Reese, 2013, Scheckler, 2003). Virtual laboratories offer a visual context for numerous abstract concepts and provide notable visualization and graphical analysis abilities (Wieman & Perkins, 2005).

Virtual lab instruments are used to save space and time. They can be more easily assembled and more properly used than real laboratory equipment, and therefore are more time efficient than traditional hands-on laboratories (Reese, 2013). They may resolve the problem of crowded groups and help the non-visual or auditory learners to interact with their learning environment (Mestre, 2006). In addition, they are cost effective since up-to-date lab equipment and supplies, in addition to their shortage, can have high operational cost in traditional laboratories (Ma & Nickerson, 2006). Dangerous experiments can be safely conducted through virtual laboratories (Scheckler, 2003). Despite all advantages, some researchers highlighted certain disadvantages such the lack of students' hands-on approach, the lack of lab partner which may facilitate peer-learning (Scheckler, 2003).

Review of Research Comparing Virtual and Traditional Laboratories

The latest modifications and progresses in educational delivery, especially in the field of technology have raised many questions concerning the effectiveness of the virtual laboratory as an instructional tool. One of the studies done in Lebanon in this domain is the one done by Zoubeir (2000). The researcher explored the impact of a constructivist approach through the use of computer projected simulations and interactive engagement approaches. The analysis of the data collected showed an improvement in the conceptual understanding of Newtonian mechanics exclusively in the experimental group that taught with the use of projected simulations. However, the research did not find a statistically significant difference between the two groups neither in students' views about physics, nor in their performances in the exams (Zoubeir, 2000).

Ma and Nickerson (2006) accomplished a literature review, of 20 articles, regarding comparative usefulness and perceptions of simulated, remote, as well as hands-on laboratories. The findings revealed that educators could not consent on the efficiency of each lab type in comparison to one another, claiming that each study had different educational outcomes and instruments/methods to measure the effectiveness. Finkelstein et al. (2006) compared the usage of PhET simulations with the usage of traditional educational resources in all the settings of teaching introductory college physics including laboratory, lecture, recitation and informal settings. They demonstrated the utility of PhET simulations in a wide array of environments in teaching undergraduate physics, and concluded that under favorable conditions those simulations could be as profitable and even more, than the traditional educational tools including textbooks, live demonstrations, and even real equipment. To document the efficiency of the use of a computer simulation, specifically the (CCK) developed by the PhET, Keller, Finkelstein, Perkins, and Pollock (2007) made a comparison between students viewing CCK and those viewing a traditional demonstration during Peer Instruction. Results showed that students viewing CCK presented a larger relative gain in conceptual understanding measures in comparison with traditional demonstrations. In a study conducted by Tüysüz (2010) on 341 chemistry students from the high school level, the influence of virtual lab on the students' achievements and attitudes were investigated. Results showed that students' attitudes towards chemistry have varied according to teaching methods used in the study, and that virtual laboratory practice had a positive influence on students' achievements and their attitudes toward chemistry when compared to traditional instruction method. Tüysüz (2010) argued that using computer in science teaching is appropriate and convenient, particularly when the content is well employed.

Similarly, Bozkurt and Ilik, carried out a research on 152 physics students at the University level aiming to assess the influence of the use of interactive computer simulations in teaching on students' achievements and beliefs about physics. For this aim, lessons were taught according to traditional instruction methods for the control group and resorting to computer simulations prepared by PhET for the experimental group. Students were subjected to a pre and post success test, as well as a 5-point Likert scale test (CLASS) used to identify their beliefs on physics and learning physics. The results showed enhancements in the students' beliefs before and after the treatment. In addition, it was noticed that groups who studied by means of computer simulations had better achievements than those who learned through traditional methods (Bozkurt & Ilik, 2010).

Shegog et al. (2012) conducted a randomized clinical control design study on a sample of 44 students from two high schools to evaluate the skills and knowledge about the molecular labs processes as well as students' attitudes towards science and computers by using HEADS UP Virtual Molecular Biology Lab as an instructional tool. The Virtual Lab was found to lead to a significant development in students' knowledge with time; however, the researcher did not notice any significant differences in science attitude scores. Similar results were found by Tsihouridis et al. (2014) who conducted a study in which students were able to use both real and virtual lab according to their educational needs. The results showed that the use of the virtual lab, as a mobile School-Lab, during teaching considerably enhanced the students' conceptual understanding of certain physics concepts. Recently, Brinson (2015) presented a review 56 articles published in and after 2005 that emphasized on comparing learning achievements by using traditional and non-traditional lab participants as experimental groups. Results proposed that most of the reviewed studies (n=50, 89%) have shown that student learning outcomes were equal or higher in "Non-traditional Lab" in comparison with "Traditional Lab" concerning all learning outcome types (knowledge and understanding, practical skills, inquiry skills, perception, analytical skills, as well as social and scientific communication).

In contrast, Quinn, King, Roberts, Carey, and Mousley (2009) found that students in some conditions could reach a better understanding of topics after hands-on laboratories, when compared to virtual labs. They concluded that it was due to the fast distraction of students while working with simulations, whereas in hands-on laboratories, students were able to maintain focus throughout their involvement. Similarly, specialized establishments for science education, like the National Science Teachers Association, emphasized the roles of hands-on activities in improving students' interest and acquisition of science skills (NSTA, 2007).

Tsihouridis, Vavougios, and Ioannidis (2013) compared the effectiveness of virtual lab and real school-labs in teaching electric circuits at Upper High-School. The analysis of the collected data showed that there was no significant difference between the two groups in their conceptual understanding of the basic concepts of electric circuits. However, some individual non-significant differences in favor of the real-lab group were observed in the 3 out of 12 teaching objectives. These results led to the conclusion that the two teaching approaches used would decisively help students to develop an investigative attitude relating to everything scientific, their cooperative skills, and their ability to express important queries with clarity and precision.

The unison of the two types of lab was tested by Zacharia (2007) who examined the worth of joining real and virtual lab experiments concerning the modification in students' conceptual understanding of electric circuits' concepts; the researcher discovered that this arrangement improved students' conceptual understanding more than the use of real lab experiments solely. Supporting the same standpoint, the American Chemical Society (ACS) stated in 2011 that computer simulations mimicking laboratory processes are likely to be valuable supplements to student hands-on activities, but could not substitute them (ACS, 2011). Tsihouridis et al. (2015) investigated the effect of the use of real and virtual lab in changing order in the teaching of the electric circuit concepts for third year high school learners. The results revealed that the order of the real and the virtual lab in the teaching process affected the understanding of the scientific concepts related to electric circuits. Tsihouridis, Vavougios, and Ioannidis (2016) found that the cyclical process of virtual and real lab, without seeming to be a straight repetition, maintained learners' interest by enhancing their critical thinking and improving the learning process.

The review of literature lacks important studies on Arabic students in general and on Lebanese ones in particular, except those done by Zgheib (2013) and Zoubeir (2000). Lebanese students rarely used the virtual lab and the new technology in their learning process due to many barriers (Zgheib, 2013). This study was conducted on Lebanese secondary school students to investigate the effect of virtual physics labs on Lebanese learners.

Purpose of the Study

Based on the above**,** this study aimed to investigate the effect of using virtual laboratory on grade 10 students' conceptual understanding of the direct current electric circuit and their attitudes towards physics in terms of students' confidence, beliefs, and teacher perception.

Research Questions

By choosing the teaching method as an independent variable, and by choosing the students' conceptual understanding and their attitudes towards physics as dependent variables, the following questions were raised:

1) Does the use of virtual laboratory affect the conceptual understanding of the direct current electric circuit of grade 10 students?
    - 1.1) Is there any significant difference in students' conceptual understanding as measured by the pre and post-test scores before and after the implementation of virtual laboratory?
    - 1.2) Is there any significant difference in students' conceptual understanding of direct current electric circuit as measured by the pre and post-test scores before and after the implementation of the interactive demonstrations using real laboratory equipment?
    - 1.3) Is there any significant difference in students' conceptual understanding, as measured by the post-test scores, between the group performing experiments using virtual laboratory and the other group taught by interactive demonstrations using real laboratory equipment?
2) Does the use of virtual laboratory produce positive attitudes towards Physics?
    - 2.1) Does the use of virtual laboratory enhance the students' confidence to learn and to perform well on physics tasks?
    - 2.2) Does the use of virtual laboratory affect the students' beliefs about the usefulness of physics and its relation to their future education?
    - 2.3) Does the use of virtual laboratory enhance students' perception of their teachers' attitudes towards them, as learners?

Method

Design

This study used a quantitative experimental pre-test versus post-test control-group design (table 1) in which students were randomly assigned into experimental and control group. The two groups were pre-tested on the dependent variables before the implementation of the study and then post-tested after the treatment has been administered.

Table 1. The experimental design of the study

Control group	O_1	O_2	T_1	O_3	O_4
Experimental group	O_1	O_2	T_2	O_3	O_4

Variables

In this study, the independent variable was the teaching method (virtual lab versus interactive demonstrations using real lab equipment). The dependent variables were the students' conceptual understanding of the direct current electric circuit and their attitudes towards physics.

Sample

The sample of this study consisted of 50 students of grade 10 from the English department of a public secondary school in Mount-Lebanon, during the academic year 2015-2016. Among the participants of this study, 26 were females and 24 were males. The sample was randomly assigned, using random number generator from SPSS statistical software, into experimental group "A" and control group "B", of 25 students each (Table 2).

Table 2. Characteristics of the participants

Group	Total	Experimental group A	Control group B
Number of students	50	25	25
Age average	15 years 4 months	15 years 6 months	15 years 3 months
Average of the previous year grades in physics	12.5	12.25	12.75
Standard deviation of the previous year grades in Physics	4.725	4.95	4.5

Data Collection Instruments

The instruments used in this research included an electricity conceptual understanding test "Determining and Interpreting Resistive Electric circuits Concepts Test" (DIRECT) and the Physics Attitude Scale (PAS).

Determining and Interpreting Resistive Electric Circuits Concepts Test (DIRECT version 1.0)

DIRECT is a diagnostic test developed by Paula Vetter Engelhardt (Engelhardt & Beichner, 2004). This test was used as pre-test and post-test in order to assess students' conceptual understanding and to compare the efficiency of virtual lab and interactive demonstrations using real lab equipment. The test is based on 11 objectives as appears in table 3. For the purpose of this research, and because two of the objectives were beyond the scope of grade 10's physics curriculum, only nine objectives were taken into consideration. The eliminated objectives were covered by four questions, which implied the omission of these questions from the test. However, this omission did not affect the validity of the test as these questions only covered the eliminated objectives and did not integrate with other objectives of the instrument. Moreover, one of the concepts that objective nine deals with is the electric field that is beyond the scope of grade 10 physics' curriculum. Therefore, the question related to electric field concept was eliminated. Hence, only 24 questions were used from this test. To test the reliability of the test after eliminating the five questions, the researcher used Kuder- Richardson formula 20. The established reliability was 0.702. To test the content validity and to ensure that the test actually measures what is intended to measure, the researcher presented the test and the corresponding objectives to two physics teachers having long experiences in the secondary teaching. They asserted that the test was valid and adequate to grade 10 physics' curriculum.

The Physics Attitude Scale (PAS)

To measure students' attitude, an attitude scale was adapted from the modified Fennema-Sherman attitude scale (Doepken, Lawsky & Padwa, n.d.). PAS was used in this study to evaluate students' attitude towards physics. Participants had to answer these statements on a 5-point Likert scale. The original test included four subscales: a confidence scale, a usefulness scale, a scale measuring physics as a male domain, and a teacher perception scale (Doepken et al., n.d.). For the purposes of this study, gender-related questions were eliminated, so the used PAS included 36 questions and three subscales of 12 questions each. The items in each of the scales were divided equally between statements that measure positive and negative attitude. The confidence scale (Co) measured self-confidence to learn and to achieve well on physics tasks. The usefulness scale (U) measured beliefs about the usefulness of physics and its relationship to students' future education. Finally, the teacher perception scale (T) measured students' perception of their teachers' attitudes towards them as learners. Items of the three scales were randomly arranged in the test (Doepken et al., n.d.). The maximum possible score on each subscale was 60 (Doepken et al., n.d.). Thus, the maximum total score that could be achieved on the PAS was 180. The reliability and validity of the physics attitude scale were established by the developer and many other investigators. The researcher recalculated the reliability (Alpha coefficient) of the 36 items of PAS that was found to be 0.981.

Table 3. The objectives of the direct test used

Objectives:
Physical Aspects of DC electric circuits (objectives 1-5):
1) Identify and explain a short circuit (more current follows the path of lesser resistance). 2) Understand the functional two-endedness of circuit elements (elements have two possible points with which to make a connection). 3) Identify a complete circuit and understand the necessity of a complete circuit for current to flow in the steady state (some charges are in motion but their velocities at any location are not changing and there is no accumulation of excess charge anywhere in the circuit).
Objectives 1-3 combined
4) Apply the concept of resistance (the hindrance to the flow of charges in a circuit) including that resistance is a property of the object (geometry of object and type of material with which the object is composed) and that in series the resistance increases as more elements are added and in parallel the resistance decreases as more elements are added. 5) Interpret pictures and diagrams of a variety of circuits including series, parallel, and combinations of the two.
Circuit layout (objectives 1-3, 5)
Current (objectives 6-7)
6) Understand and apply conservation of current (conservation of charge in the steady state) to a variety of circuits. 7) Explain the microscopic aspects of current flow in a circuit through the use of electrostatic terms such as electric field, potential differences, and the interaction of forces on charged particles.
Potential difference (Voltage) (objectives 8-9)
8) Apply the knowledge that the amount of current is influenced by the potential difference maintained by the battery and resistance in the circuit. 9) Apply the concept of potential difference to a variety of circuits including the knowledge that the potential difference in a series circuit sums while in a parallel circuit it remains the same.
Current and voltage (objectives 6 and 9)
Energy (Eliminated objectives)
▪ Apply the concept of power (work done per unit time) to a variety of circuits.
▪ Apply a conceptual understanding of conservation of energy including Kirchhoff's loop rule (V=0 around a closed loop) and the battery as a source of energy.

Procedures

To achieve the goal of this research, the sample was randomly assigned into two equal groups of 25 students each. Group "A" was chosen to be the experimental group while Group "B" was chosen to be the control group. The first researcher taught both groups the same content over 10 weeks for three periods per week, of 55 minutes each. The two classes were videotaped, and a randomly selected sample of the videotapes was observed to insure authenticity of the treatment, and to make sure the teacher was implementing the activities as described in the lesson plans. At the beginning of the academic year 2015-2016, each student of each of the two groups completed as pre-tests the DIRECT and the PAS, during 40 minutes and 20 minutes respectively, to investigate their conceptual understanding and attitudes towards physics before the research started. A computer training session was conducted for all students of the experimental group during one period of 55 minutes in which the teacher introduced the PhET simulation software, which will be discussed in the next paragraph, and directed students to some sample laboratory activities.

Both control and experimental groups were taught using structured inquiry activities where both problem matters and procedures were presented. Each two students of the experimental group performed in a virtual laboratory environment, using PhET simulations, a series of experimental activities that were compatible with the curriculum objectives and the DIRECT test objectives. Based on the objectives of the taught chapters, six experiments were conducted in chapter two, four experiments in chapter three, and four experiments in chapter four. For the control group "B", the teacher conducted interactive demonstrations of the same experiments in traditional laboratory settings using real equipment. To carry out the required experiment in the control group, the researcher provided some of the unavailable equipment needed to conduct the experiments. The lack of laboratory equipment from one side and the students' skills from the other side and many other reasons aforementioned in the rationale of this study obliged the teacher to carry out the experiments by herself. Finally, at the beginning of April, the researcher realized the post-tests. Students of both groups were retested, for 40 minutes, using the same DIRECT test. Also, both groups recompleted, during 20 minutes, the same PAS questionnaire.

PhET Simulation

Physics Education Technology (PhET), are one example of the virtual laboratories' software and was established by the University of Colorado that covered the curriculum of introductory physics. All simulations are gratis, and can be accessed online or by downloading for off-line use (Finkelstein et al., 2006). PhET simulations create a highly-interactive atmosphere when it comes to user control, active feedback, and use of multiple representations (Podolefsky, Perkins, & Adams, 2010). The simulations are scientifically accurate, and offer highly illustrative, dynamic representations of principles of physics. At the same time, these simulations play a role in building links between students' daily understanding of the real world and the underlying principles of physics, by making clear the physical models (Finkelstein et al., 2006). They also offer balanced challenges and embedded puzzles that are achievable according to the level of student, thus promoting students' inquiry (Podolefsky et al., 2010). One of the PhET simulations is the Circuit Construction Kit (CCK). Perkins et al (2006) asserted that the use of the CCK may enable students to carry out experimentations in a similar way to real laboratories. Electric components have default parameters that can be regulated by the user to see the simultaneous changes produced. The CCK simulation's model is based on Kirchhoff's laws to accurately describe current and voltage in direct current circuits (Perkins et al., 2006). One of CCK's most noticeable features is its explicit and clear visual illustration of current flow, which is symbolized by small blue spheres that model the behaviour of electrons. This visual model for current may allow the user to visualize and understand how current flows in a circuit just like experts think about the current flow (Perkins et al., 2006). Upon the features discussed above, the researcher used the PhET simulation to perform experiments in virtual laboratory. Special, CCK was used in this study to perform virtual experiments.

Results and Discussion

Results Related to Research Question One

To answer the first research question, an independent T-test was conducted on the pre-test scores of DIRECT. The results of table 4 showed that there was no significant difference between the mean scores of the two groups ($p = 0.750$), revealing that the two groups do not differentiate at the beginning of the study. To test whether the contribution of virtual lab and interactive demonstrations using real lab equipment produces a conceptual understanding of the direct current electric circuit of grade 10 students, a comparison between the pre and the post-test score was done each group. Figure 1 displays the mean scores for each group (A and B) on the pre-test and the post-test, as well as the improvement score. In addition, the researcher conducted a paired T-test to compare the pre and the post-test scores of both groups. Table 5 shows that there was a significant difference in the scores of pre and post-test for the control group ($p = 0.000$) and for the experimental group ($p = 0.000$).

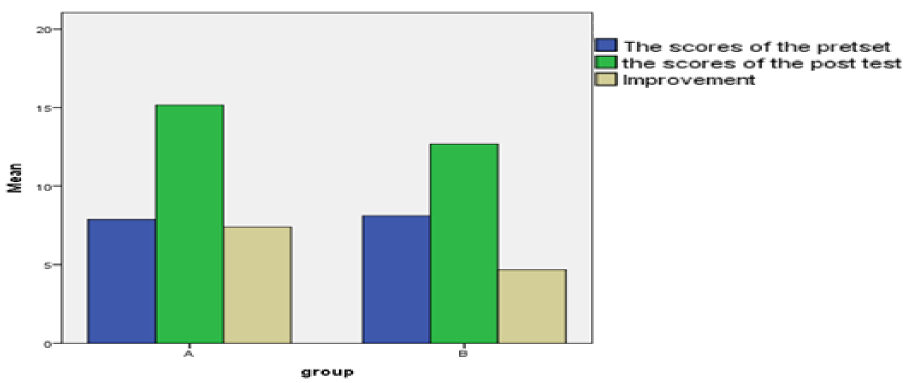

Figure 1. Mean scores of pre and post DIRECT test

Table 4. Independent samples t-test comparing DIRECT pre-test scores

		Levene's Test for Equality of Variances		T-test for Equality of Means						
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
The scores of the pre-test	Equal variances assumed	1.048	.311	-.321-	48	*.750*	-.240-	.748	-1.743-	1.263
	Equal variances not assumed			-.321-	46.605	.750	-.240-	.748	-1.744-	1.264

Table 5. Paired t-test conducted on DIRECT pre and post-test

		Paired Differences					t	Df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	The scores of the experimental group "A" on the pre-test - The scores of the experimental group "A" on the post-test	-7.280-	4.067	.813	-8.959-	-5.601-	*-8.949-*	24	*.000***
Pair 2	The scores of the control group "B" on the pre-test - The scores of the control group "B" on the post-test	-4.560-	3.874	.775	-6.159-	-2.961-	*-5.886-*	24	*.000***

In the aim to compare the conceptual understanding of the direct current electric circuit of the students in the control group to that in the experimental group, the researcher conducted, an independent T-test on the scores of the DIRECT post-test. A significant difference was found between the scores of the two groups (p = 0.031) as appear in table 6.

Table 6. Independent samples t-test comparing groups' DIRECT post-test scores

		Levene's Test for Equality of Variances		T-test for Equality of Means						
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
the score of the post-test	Equal variances assumed	.340	.563	*2.217*	48	*.031**	2.480	1.119	.231	4.729
	Equal variances not assumed			2.217	47.934	.031*	2.480	1.119	.231	4.729

*. Significant at the 0.05 level (2-tailed).

Further analysis on the scores of each objective was done. The score of each objective was calculated as the sum of the scores of the questions that covered it. The result of the independent T-test conducted on the scores of the objectives of the DIRECT post-test (Table 7), showed that there was a significant difference between the two groups only on the scores of the objective 7 (p = 0.001) and the scores of objective 8 (p = 0.014).

Table 7. Independent samples t-test comparing DIRECT objectives post-test scores

		Levene's Test for Equality of Variances		T-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
the score of the objective 1	Equal variances assumed	12.473	.001	.755	48	.454	.160	.212	-.266-	.586
	Equal variances not assumed			.755	32.116	.456	.160	.212	-.272-	.592
the score of the objective 2 & 3	Equal variances assumed	1.282	.263	.000	48	1.000	.000	.165	-.332-	.332
	Equal variances not assumed			.000	45.280	1.000	.000	.165	-.332-	.332
the score of the objectives 1 & 3 combined	Equal variances assumed	.000	1.000	.000	48	1.000	.000	.123	-.248-	.248
	Equal variances not assumed			.000	48.000	1.000	.000	.123	-.248-	.248
the score of the objective 4	Equal variances assumed	.193	.663	.894	48	.376	.240	.269	-.300-	.780
	Equal variances not assumed			.894	47.996	.376	.240	.269	-.300-	.780
the score of the objective 5	Equal variances assumed	2.912	.094	.491	48	.626	.120	.244	-.371-	.611
	Equal variances not assumed			.491	47.362	.626	.120	.244	-.372-	.612
the score of the objective 6	Equal variances assumed	3.646	.062	.687	48	.496	.120	.175	-.231-	.471
	Equal variances not assumed			.687	45.382	.496	.120	.175	-.232-	.472
the score of the objective 7	Equal variances assumed	2.395	.128	3.494	48	*.001***	.680	.195	.289	1.071
	Equal variances not assumed			3.494	44.471	*.001***	.680	.195	.288	1.072
the score of the objective 8	Equal variances assumed	.020	.889	2.558	48	*.014**	.680	.266	.146	1.214
	Equal variances not assumed			2.558	47.956	*.014**	.680	.266	.145	1.215
the score of the objective 9	Equal variances assumed	.860	.358	1.155	48	.254	.400	.346	-.297-	1.097
	Equal variances not assumed			1.155	47.852	.254	.400	.346	-.297-	1.097
the score of the objectives 6 & 9 combined	Equal variances assumed	1.137	.292	.568	48	.573	.080	.141	-.203-	.363
	Equal variances not assumed			.568	47.946	.573	.080	.141	-.203-	.363

*. Significant at the 0.05 level (2-tailed).
**. Significant at the 0.01 level (2-tailed).

Results Related to Research Question Two

First, an independent T-test was conducted to compare the PAS pre-test total scores and scores of the subscales, for the two groups. The results of the total score (p = 0.720), the confidence subscale score p = 0.879, the usefulness subscale score (p = 0.911), and the teacher perception subscale score (p = 0.409) did not present any significant difference between the two groups as shown in table 8. These results revealed that the two groups did not differentiate regarding the attitude before the implementation of the study.

In the aim of investigating whether the contribution of each teaching method (virtual lab versus interactive demonstrations using real lab) produced a better positive attitude towards physics, the researcher compared the means of the total score of PAS as well as the score of each of its subscales, before and after the implementation of the study, for both control and experimental group. Figure 2 displays, for each of the two groups, the mean of the total score of PAS of the pre-test and the post-test as well as the mean score of each subscale. Comparing the pre and the post-test scores of PAS, the result of the paired T-test (table 9) for the experimental group (p = 0.000) presented a significant difference. However, no significant difference was presented for the control group (p=0.238).

Table 8. Comparison between PAS and its subscales pre-test scores

		Levene's Test for Equality of Variances		T-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
the score of the pre-test	Equal variances assumed	1.124	.294	-.361-	48	.720	-1.920-	5.319	-12.614-	8.774
	Equal variances not assumed			-.361-	45.079	.720	-1.920-	5.319	-12.632-	8.792
the total of subscale *Co*	Equal variances assumed	1.699	.199	-.153-	48	.879	-.400-	2.610	-5.649-	4.849
	Equal variances not assumed			-.153-	46.561	.879	-.400-	2.610	-5.653-	4.853
the total of subscale *U*	Equal variances assumed	1.688	.200	-.113-	48	.911	-.240-	2.126	-4.514-	4.034
	Equal variances not assumed			-.113-	44.438	.911	-.240-	2.126	-4.523-	4.043
the total of subscale *T*	Equal variances assumed	.341	.562	-.833-	48	.409	-1.280-	1.537	-4.370-	1.810
	Equal variances not assumed			-.833-	47.933	.409	-1.280-	1.537	-4.370-	1.810

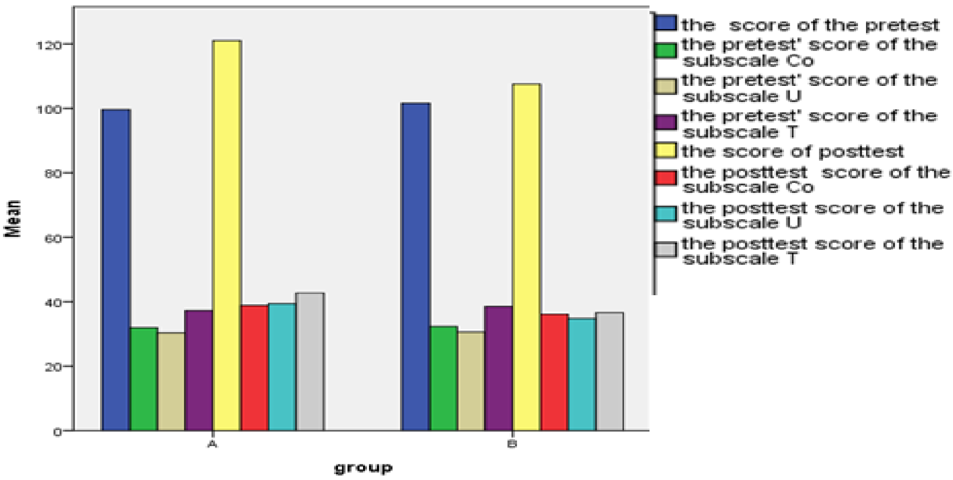

Figure 2. Means of the PAS and each subscale scores

Table 9. Paired t-test conducted on PAS pre and post-test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	the total score of the pre-test of the group A - the total score of the post-test of the group A	-21.360-	23.668	4.734	-31.130-	-11.590-	-4.512-	24	*.000***
Pair 2	the total score of the pre-test of the group B - the total score of the post-test of the group B	-5.920-	24.447	4.889	-16.011-	4.171	-1.211-	24	.238

**. Significant at the 0.01 level (2-tailed).

In order to investigate whether the use of virtual laboratory produced positive attitudes towards Physics, the total scores and the subscales scores of the PAS post-test were analysed. The mean of the experimental group was slightly greater than the mean of the control group as appears in table 10. On the other hand, as shown in table 10, the mean scores of the subscales of the experimental groups were slightly higher than those of the control group. However, as shown in table 11, the result of the independent T-test conducted on the total scores of the PAS post-test did not present significant difference nor regarding students' attitudes towards physics between the two groups, neither regarding the subscales, except in the teacher perception subscale ($p = 0.046$).

Table 10. Descriptive statistics of the PAS post-test scores

	group	N	Mean	Std. Deviation	Std. Error Mean
the score of the PAS post-test	A	25	121.00	31.278	6.256
	B	25	107.48	34.328	6.866
the score of post-test of the subscale *Co*	A	25	38.88	10.948	2.190
	B	25	36.08	12.430	2.486
the score of post-test of the subscale *U*	A	25	39.40	11.225	2.245
	B	25	34.76	11.837	2.367
the score of post-test of the subscale *T*	A	25	42.72	10.188	2.038
	B	25	36.64	10.743	2.149

Table 11. Comparison between PAS post-test and its subscales scores

		Levene's Test for Equality of Variances		T-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
the score of post-test of PAS	Equal variances assumed	.535	.468	1.456	48	.152	13.520	9.288	-5.155-	32.195
	Equal variances not assumed			1.456	47.590	.152	13.520	9.288	-5.159-	32.199
the score of post-test of the subscale *Co*	Equal variances not assumed			1.456	47.590	.152	13.520	9.288	-5.159-	32.199
	Equal variances not assumed			.845	47.247	.402	2.800	3.313	-3.863-	9.463
the score of post-test of the subscale *U*	Equal variances assumed	.161	.690	1.422	48	.161	4.640	3.263	-1.920-	11.200
	Equal variances not assumed			1.422	47.865	.161	4.640	3.263	-1.920-	11.200
the score of post-test of the subscale *T*	Equal variances assumed	.301	.586	2.053	48	*.046**	6.080	2.961	.126	12.034
	Equal variances not assumed			2.053	47.866	*.046**	6.080	2.961	.126	12.034

*. Significant at the 0.05 level (2-tailed).

Discussion

Discussion Related to the First Research Question

Data collected from the DIRECT test were addressed to answer the first research question. The analysis of the DIRECT post-test results showed that students of the experimental group that used the virtual laboratory performed significantly better than those of the control group who were taught through interactive demonstrations using real lab equipment. In spite of the small size of the sample, testing by the DIRECT test showed clearly that the use of virtual laboratory induced a considerable change in students' conceptual understanding of the direct current electric circuit. The significant difference between the two groups appeared mainly in the questions of the objective 7 and the objective 8 that are related to the microscopic aspect of the electric current and the relation between the current, the resistance in the circuit, and the potential difference applied. This result may be due to the property of the Circuit Construction Kit (CCK) simulation of PhET that explicitly explains the microscopic aspect of the direct current. The CCK represents the invisible electrons with blue spheres and shows their supposed motion inside the circuit, and how this motion can be affected with the resistance in the circuit of the potential difference of the source; therefore, it demonstrates how the light of the bulb changes and then how the amount of current changes with the previous mentioned factors. Such visualizations cannot be done by means of traditional real lab (Perkins et al., 2006). Therefore, the importance of virtual laboratories has lied in its ability to introduce the concepts by referring to the microscopic level in contrast to the real lab that only shows the macroscopic properties (Wieman & Perkins, 2005).

The findings of this research affirm the ones of previous studies such as Finkelstein et al. (2006), Shegog et al. (2012), Tüysüz (2010), Tsihouridis, Vavougios, and Ioannidis (2013), and Zoubeir (2000). However, the results of this research are not compatible with some previous researches such as those done by ACS (2011), NSTA (2007), Quinn et al. (2009), Tsihouridis et al. (2014), and Zacharia (2007). The inconsistency in this study's findings with some earlier researches may be due to the type of the concepts taught, type of the virtual laboratory used, the intervention of extraneous variables, the size of the sample, the various designs used, the statistical analysis and many other reasons. Consequently, more researches are needed in this domain.

Discussion Related to the Second Research Question

To assess the effect of the use of virtual laboratory on students' attitude towards physics, data collected from PAS were analysed. Results indicated that attitudes of the experimental group students towards physics significantly improved after the treatment in a general perspective, and in subscales perspective. However, except for the usefulness subscale, there was no significant improvement in the attitudes of the control group students in general, neither in the other two subscales. However, there were no significant differences between the experimental and the control group regarding students' attitudes towards physics. This finding is similar to the results of some studies such as Shegog et al. (2012), and Zoubeir (2000). However, it contradicts the results of the study done by Bozkurt and Ilik (2010), and Tüysüz (2010), where attitudes of students towards chemistry have improved and positively influenced when compared to those of the traditional teaching. The lack of significant difference between the experimental group and the control group regarding students' attitudes towards physics may be due to many reasons. One of these reasons can be attributed to language problems. It may be difficult for non-English speakers to understand the questions of PAS that are related to their confidence to learn physics, to their beliefs about usefulness of physics, and to students' perception of their physics teachers and what their teachers think of the students' physics levels.

Regarding the subscales of PAS, there was no significant difference between the two groups in the confidence and the usefulness subscales. However, in the experimental group, the third subscale that measures the students' perception of their teachers' attitudes towards them as learners was significantly better than that of the control group. This may be due to the previous teaching approaches used in the former classes. Most of the participating students came from public schools that, according to Zgheib (2013), lack the presence of integrated technology system. The use of virtual laboratory might have stimulated the students to realize experiments. Many students conducted at home various un-required experiments and activities, using the various PhET simulations that were installed on their own laptops, and had discussed it in the next day with the teacher who continuously encouraged them to seek new knowledge by all the possible means. Students showed, through this discussion, an enthusiasm to learn and to explore. All this may have affected their perception about the teacher and thus have produced the remarked significant different in the teacher perception subscale.

Conclusion

The analysis of the gathered data clearly presents that after 10 weeks of treatment, students significantly improved in term of conceptual understanding of the direct current electric circuit in both experimental and control groups. Moreover, the mean score of the experimental group students was better and showed some difference compared to that of the control group. Regarding the attitudes towards physics, the collected data did not show any significant difference between the two groups except in the teacher perception subscale. These results led to the conclusion that:

- The use of either teaching method (virtual laboratory or interactive demonstrations using real lab) enhances the conceptual understanding of students.
- The use of virtual laboratory has a better effect than the interactive demonstrations using real lab equipment regarding the conceptual understanding of the direct current electric circuit.
- the use of virtual laboratory does not influence the attitudes more than the real lab does.
- the use of virtual laboratory promotes the students' perception of their teachers' attitudes towards them as learners.

Recommendations

The findings of this study may be a platform for further future researches.

First, three chapters of the electricity unit were the fertile fuel of this study. In order to be able to generalize the results it is important to investigate the effect of virtual laboratory on other domains like mechanics, waves, optics, or in the domains where experiments cannot be conducted in the school lab like relativity and radioactivity.

Second, the DIRECT post-test was administrated to the students directly after the implementation of the study. It is highly recommended to detect the degree of the retention this sample of students will still have after a long period of time by testing the long term retention of the gained concepts, for the same sample of students, at the end of the academic year or even at the beginning of their next academic year in grade 11.

Third, many researchers highlighted the point related to students' practical laboratory skills that may be negatively affected by using virtual laboratory. It is necessary to guide a research that investigates how the use of virtual laboratory may affect these skills.

References

Alameh, S. K. (2013). *The impact of using computers as cognitive tools on grade 10 Lebanese students' attitudes and conceptual understanding in physics*. Unpublished master thesis. American university of Beirut. Beirut, Lebanon.

Aldrich, C. (2005). *Learning by doing: A comprehensive guide to simulations, computer games, and pedagogy in e-Learning and other educational experiences*. San Francisco, CA: Wiley, Pfeiffer.

American Chemical Society. (2011). Importance of hands-on laboratory activities. *American Chemical Society Public Policy Statement*. Retrieved from:
https://www.acs.org/content/dam/acsorg/policy/publicpolicies/invest/computersimulations/hands-on-science.pdf

Bozkurt, E., & Ilik, A., (2010). The effect of computer simulations over students' beliefs on physics and physics success. *Procedia Social and Behavioral Sciences*, *2*(2), 4587–4591. doi:10.1016/j.sbspro.2010.03.735

Brinson, J. R. (2015). Learning outcome achievement in non-traditional (virtual and remote) versus traditional (hands-on) laboratories: A review of the empirical research. *Computers & Education*, *87*, 218-237.
doi: 10.1016/j.compedu.2015.07.003

Centre for Educational Research and Development (CERD). (1995). *New Lebanese educational ladder*. Beirut, Lebanon: CERD.

Doepken, D., Ellen, L., & Linda , P. (n.d.). *Modified fennema-sherman attitude scales*. Retrieved from:
http://www.stuckonscience.org/StuckonScience/Teachers_Only/Entries/2014/3/19_Fixed_vs._Growth_Mindset__Awareness_comes_First!_(Part_1)_files/Math%20Attitude%20Self%20Survey.doc

Engelhardt, P., & Beichner, R., J. (2004). Students' understanding of direct current resistive electrical circuits. *American Journal of Physics*, *72*(1), 98-115. doi: 10.1119/1.1614813

Finkelstein, N. D., Adams,W. K., Keller, C. J., Perkins, K. K., Wieman, C., &, the Physics Education Technology Project Team. (2006). High-tech tools for teaching physics: the physics education technology project. *MERLOT Journal of Online Learning and Teaching*, *2*(3), 110-120. Retrieved from: http://jolt.merlot.org/vol2no3/finkelstein.pdf

Halloun, I. A. (1996). Schematic modeling for meaningful understanding of physics. *Journal of research in science teaching*, *33*(9), 1019 -1041.

doi:10.1002/(SICI)1098-2736(199611)33:9<1019::AID-TEA4>3.0.CO;2-I

Halloun, I. A., & Hestenes, D. (1985). The initial knowledge state of college physics students. *American Journal of Physics*, *53*(11), 1043-1048. doi: 10.1119/1.14030

Keller, C. J., Finkelstein, N. D., Perkins, K. K. & Pollock, S. J. (2007). Assessing the Effectiveness of a Computer Simulation in Introductory Undergraduate Environments. In *Proceedings of AIP Conference, 883*. doi: 10.1063/1.2508707

Lkhagva, O., Ulambayar, T., & Enkhtsetseg, P. (2012). Virtual laboratory for physics teaching. In *Proceedings of the International Conference on Management and Education Innovation, IPEDR, 37,* Singapore (PP. 319-323). Retrieved from: http://www.ipedr.com/vol37/062-ICMEI2012-E10015.pdf

Ma, J., & Nickerson, J. V. (2006). Hands-on, simulated, and remote laboratories: a comparative literature review. *ACM Computing Surveys*, *38*(3), 1-24. doi: 10.1145/1132960.1132961

Mallory, C. R., (2012). *Evaluating learning outcomes in introductory chemistry using virtual laboratories to support inquiry based instruction* (Doctoral dissertation). Retrieved from ProQuest Dissertations and Theses database. (UMI No.3522177)

McDermott, L. C. (2001). Oersted Medal Lecture 2001: "Physics Education Research—The Key to Student Learning". *American Journal of Physics*, *69*(11), 1127-1137. doi: 10.1119/1.1389280

Mestre, L. (2006). Accommodating Diverse Learning Styles in an Online Environment. *Reference & User Services Quarterly*, *46*(2), 27-32. Retrieved from: http://www.jstor.org/stable/20864644

National Science Teachers Association. (2007). *NSTA Position Statement: The Integral Role of Laboratory Investigations in Science Instruction.* Retrieved from: http://www.nsta.org/about/positions/laboratory.aspx

Onyesolu, M. O. (2009). Virtual Reality Laboratories: An Ideal Solution to the Problems Facing Laboratory Setup and Management. In *Proceedings of the World Congress on Engineering and Computer Science 2009 (WCECS 2009) I*, San Francisco, USA. doi:10.1016/j.compedu.2016.02.002

Perkins, K., Adams, W., Dubson, M., Finkelstein, N., Reid, S., Wieman, C., &LeMaster, R. (2006). PhET: Interactive simulations for teaching and learning physics. *The Physics Teacher, 44*(1), 18-23. doi: 10.1119/1.2150754

Podolefsky, N. S., Perkins, K. K., and Adams, W. K., (2010). Factors promoting engaged exploration with computer simulations. *The American Physical Society*, (6)2, 020117/1-020117/11.

doi: 10.1103/PhysRevSTPER.6.020117

Quinn, J. G., King, K., Roberts, D., Carey, L., & Mousley, A. (2009). Computer-based learning packages have a role, but care needs to be given as to when they are delivered. *Bioscience Education*, *14*(1). doi: 10.3108/beej.14.5

Reese, M. C. (2013). *Comparison of student achievement among two science laboratory types: Traditional and virtual* (Doctoral dissertation). Retrieved from ProQuest Dissertations and Theses database. (UMI No 3590234)

Scheckler, R. K. (2003). Virtual labs: a substitute for traditional labs? *International Journal of Developmental Biology*, *47*, 231-236. Retrieved from:

http://www.ijdb.ehu.es/web/descarga/paper/12705675

Shegog, R., Lazarus, M. M., Murray, N. G., Diamond, P. M., Sessions, N., Zsigmond, E. (2012).Virtual transgenics: Using a molecular biology simulation to impact student academic achievement and attitudes. *Research in Science Education*, *42*(5), 875-890. doi:10.1007/s11165-011-9216-7

Tsihouridis Ch., Vavougios D., &Ioannidis G. S. (2013). The effectiveness of virtual laboratories as a contemporary teaching tool in the teaching of electric circuits in Upper High School as compared to that of real labs. In Auer M.E. (Eds.), In *Proceedings of the* 16^{th} *International Conference on Interactive Collaborative Learning ICL 2013 & the* 42^{nd} *International Conference on Engineering Pedagogy IGIP 2013*, Kazan, Russia (pp. 816-820). doi: 10.1109/ICL.2013.6644714

Tsihouridis Ch., Vavougios D., Ioannidis G. S., Alexias A., Argyropoulos Ch., Poulios S. (2014). Using sensors and data-loggers in an integrated mobile school-lab setting to teach Light and Optics. In Auer M.E. (Eds.) Proceedings of 2014 International Conference on Interactive Collaborative Learning, (ICL2014), Dubai (pp. 439-445). doi: 10.1109/ICL.2014.7017813

Tsihouridis Ch., Ioannidis, G.S., Vavougios D., Alexias A., Argyropoulos Ch., Poulios S. (2015, September). The effect of teaching electric circuits switching from real to virtual lab or vice versa – A case study with junior high-school learners. In *Proceedings of 2015 International Conference on Interactive Collaborative Learning (ICL),* Florence, Italy (pp. 643-649). DOI: 10.1109/ICL.2015.7318102

Tsihouridis Ch., Vavougios D., Ioannidis G. (2016, September). The effect of switching the order of experimental teaching in the study of simple gravity pendulum – A study with junior high-school learners. In Auer et al. (Eds.). In *Proceedings of 19th International Conference on Interactive Collaborative Learning (ICL2016), and 45th IGIP International Conference on Engineering Pedagogy,* Belfast (pp. 877 – 890). doi: 10.1007/978-3-319-50337-0_47

Tüysüz C. (2010). The Effect of the virtual laboratory on students' achievement and attitude in chemistry. *International Online Journal of Educational Sciences*, *2*(1), 37-53.

Retrieved from: http://www.iojes.net//userfiles/Article/IOJES_167.pdf

Wieman, C., & Perkins, K. (2005). Transforming physics education. *Physics Today*, *58*(11), 36-41.

doi: 10.1063/1.2155756

Zacharia, Z. C. (2007). Comparing and combining real and virtual experimentation: an effort to enhance students' conceptual understanding of electric circuits. *Journal of Computer Assisted Learning*, *23*(2), 120-132. doi: 10.1111/j.1365-2729.2006.00215.x

Zgheib R. S. (2013). *Organizational support of technology integration in one school in Lebanon* (Doctoral dissertation). Retrieved from ProQuest Dissertations and Theses database. (UMI No. 3596298)

Zoubeir, W. F. (2000). *Grafting computer projected simulations and interactive engagement methods within a traditional classroom setting: the influence on secondary level students' understanding of Newtonian mechanics and on attitudes towards physics* (Doctoral dissertation). Retrieved from ProQuest Dissertations and Theses database. (UMI No. 9988370)

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The Evaluation of Conceptual Learning and Epistemological Beliefs on Physics Learning by Think-Pair-Share

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Abstract

The purpose of the research was to investigate the effects of think pair share (TPS) instructional strategy on students' conceptual learning and epistemological beliefs on physics and physics learning. The research was conducted with two groups. One of the groups was the experimental group (EG) and the other group was the control group (CG). 35 students in the experimental group were instructed with think pair share instructional strategy while 36 students in the control group were instructed with conventional, teacher-centered teaching. Data were collected using "Mechanics Baseline Test (MBT)" which is used to monitor the conceptual learning of the students, "Colorado Learning about Science Survey (CLASS)" which is used to search for the epistemological beliefs on physics and physics learning of the students and students' opinions about think pair share instructional strategy. The results of the research revealed that think pair share instructional strategy had more positive effect on students' conceptual learning and epistemological beliefs on physics learning than conventional teacher-centered teaching. The students in the experimental group also changed their perspective on conceptual learning and found the instructional strategy enjoyable. Besides, some suggestions based on the findings were presented at the end of research.

Introduction

Learning physics is quite difficult and a complex process thus many students do not generally like to learn the fundamental principles and concepts regarding physics course (Gok, 2015; Hake, 1998; Madsen, McKagan, & Sayre, 2015; Mazur, 1997). Students may learn the fundamental principles and concepts of the physics individually while instructor teaches the learning materials with the help of conventional, teacher centered teaching in the classroom but the usage of this teaching approach might not improve the learning physics of the students. Students may need to take an active role in learning physics. Therefore they should interact with their classmates, discuss the learning materials, and teach the fundamental principles and concepts of the physics each other.

Conventional, teacher centered teaching is generally considered to comprise of a course syllabus, textbooks covered chapters and standard problems, and predefined or prepared manuals for various laboratories (McDermott, 1991). This teaching method is based on teacher centered approach and students do not usually think about the fundamental concepts because everything based on the knowledge is readily given to the students by the instructors. The students begin to memorize concepts, formulas, and fundamental principles without scientific reasoning (Gok, 2013). It could be said that conventional, teacher centered teaching is not sufficient to comprehend the fundamental principles of the physics for learners. One of the leading physics education researchers is McDermott (2001) reported the inefficacy of the conventional teaching in her reputable research as follows: 1) "facility in solving standard quantitative problems is not an adequate criterion for functional understanding", 2) "connections among concepts, formal representations, and the real world are often lacking after traditional instruction", 3) "certain conceptual difficulties are not overcome by traditional instruction", 4) "a coherent conceptual framework is not typically an outcome of traditional instruction", 5) "growing in reasoning ability often does not result from traditional instruction", finally 6) "teaching by telling is an ineffective mode of instruction for most students" (p.1130-1133). This research and many others (McDermott, 1993; Puente & Swagten, 2012; Redish, Saul, & Steinberg, 1998; Seung, 2013; Van Heuvelen, 1991) were indicated that the conventional, teacher centered teaching is not sufficient to understand scientific knowledge effectively, to solve quantitative and qualitative problems, to enhance scientific reasoning skills, and to improve critical and analytical thinking skills for learners (Fraser et al. 2014; Gok, 2012; Gok, 2015; Kuo & Wieman, 2016).

Several studies (Caballero et al., 2012; Domert, Airey, Linder, & Kung, 2007; Hake, 1998; Hammer, 1994; Hammer, 1995; Lising & Elby, 2005; May & Etkina, 2002; Roth & Roychoudhury, 1994; Sharma, Ahluwalia, Sharma, 2013; Stathopoulou & Vosniadou, 2007) revealed that the conceptual development of the students have a strong relationship between cognitive understanding of the students and students' epistemological beliefs about physics and physics learning with the help of interactive engagement methods instead of conventional, teacher centered teaching. Thus many interactive engagement methods and effective instructional strategies based on active learning have been steadily developed by the researchers (Hake, 1998; Mazur, 1997; McDermott, 1993; Redish, 2003). One of the effective instructional strategies is think pair share (TPS). Think pair share instructional strategy is an active learning and teaching strategy. The theoretical framework of think-pair-share instructional strategy depends on Bandura's social cognitive theory. The cognitive theory explains the relationships between behaviors, personal factors, and environmental factors (Trent, 2013).

Kothiyal, Majumdar, Murthy, & Iyer (2013) also asserted that think pair share instructional strategy consists of several theoretical bases including interactive engagement, cooperative learning, and wait-time. Cooperative learning is the heart of many active learning strategies (Johnson, Johnson, & Smith, 1991). Cooperative learning provides students the opportunity to work together, it allows students to establish relationship between new information and existing knowledge, and it fosters the sense of responsibility of the students between pairs in order to fulfill targeted goals and objectives (Trent, 2013).

Think pair share instructional strategy like "peer instruction" (Mazur, 1997) is cooperative learning. Johnson & Johnson (1999) determined the five main components of cooperative learning. The first component is positive interdependence. This refers to a strong relationship between pairs for completing the groups' task. The second component is face-to-face promotive interaction. It shows that students encourage and motivate each other's learning by helping. The students explain and teach the learning materials each other. The third component is individual accountability. This means that the performance of each student is generally evaluated and the results are given to the group and/or the individual. The fourth component is interpersonal and small group skills. It indicates that students need to communicate with each other effectively. The small group skills refer to leadership, decision-making, trust-building, communication, and conflict-management skills. The last component is group processing. This means that students in groups and/or pairs need to determine targeted academic achievements and objectives. These components may also be valid for think pair share instructional strategy.

Think pair share instructional strategy provides students the opportunities to check their learning by means of formative assessment with their partners. It also may enable students to focus on concepts, to discuss around a concept or a quantitative and qualitative problem, to exchange the ideas and thoughts with each other of the students, to solve the problems, to promote higher-level thinking, to improve critical and analytical thinking skills during the discussion between pairs/partners, to be active throughout a class period, and to increase the attention (Cortright, Collins, & DiCarlo, 2005; Gok, 2015; Sampsel, 2013; Smith et al. 2009).

Think pair share instructional strategy is quite simple, flexible, and economical method. Preliminary works for the courses in the instructional strategy are generally easy and do not take a long time of the instructors. The instructional strategy can easily be conducted with the small groups or the large groups and used during any stage of teaching and learning in many disciplines (Allen & Tanner, 2002; Kothiyal et al. 2013; Prahl, 2017; Raba, 2017; Trent, 2013).

The application procedure of think-pair share instructional strategy consists of three steps. Students study on a question posed by the instructor, initially individually, secondly in pairs or groups and finally together with the entire class (Allen & Tanner, 2002; Kothiyal et al. 2013). The instructor does not directly present the knowledge to the class but instead the instructor guides and helps students with learning process as the students work cooperatively with their partners (Barkley, Cross, & Major, 2005; Johnson et al. 1991; Silberman, 1996). The instructor also evaluates the understanding of the students by listening and observing many groups during discussion and then the instructor interprets their responses before s/he explains an effective summative assessment to the class (Gok, 2013).

There is not sufficient studies performed on think pair share instructional strategy based on active learning in Turkey. Therefore the researcher examined and reported the effects of think pair share instructional strategy on Turkish university students' academic performance and epistemological beliefs on physics and physics learning in order to make a contribution in the literature. The purpose of the present study was to examine epistemological beliefs of the students on physics and physics learning and conceptual learning of the students by using different instructional strategies (think pair share instructional strategy in the experimental group, conventional, teacher centered teaching in the control group). The conceptual learning of the students and epistemological beliefs on physics and physic learning of the students were evaluated with two different instruments. The conceptual learning of the students was evaluated with Mechanics Baseline Test (MBT) and the epistemological beliefs on physics and physics learning of the students were evaluated with Colorado Learning about Science Survey (CLASS). Also the opinions of the students in the experimental group concerning the applied instructional strategy were collected with an essay. The research questions examined were:

1. Are there any difference between the experimental group and the control group students' conceptual learning?

2. Are there any difference between the experimental group and the control group students' epistemological beliefs on physics and physics learning?

3. Does the teaching of think pair share instructional strategy change students' perspectives about conceptual learning and epistemological beliefs on physics and physics learning?

Method

A two group, pre-test and post-test, quasi-experimental design with a control group was conducted in the present study. Complete sections of an introductory calculus-based physics course were assigned to treatment and non-treatment conditions. In this section, firstly the participants of the research could be presented, secondly the applied instructional approaches could be explained and finally the data collection and data analysis of the research could be detailed as follows.

Participants

The study was performed at Dokuz Eylul University in Izmir, Turkey. The study sample consisted of 71 first-year students from two different sections of an introductory calculus-based physics course where the sections were randomly assigned to two groups. One of them was the experimental group (EG). This group consisted of 35 students. The other section was the control group (CG). This group comprised of 36 students. This course for science and engineering students covers vector displacement, uniform and accelerated motion, force, momentum, energy, rotating systems, oscillations, and an introduction to thermodynamics. The researcher examined the academic background of the students including the experimental group and the control group (by their GPA "Grade-Point Average" and University entrance scores), and the differences in these scores were not statistically significant.

Instructional Approaches

The research was conducted with two groups during nine weeks. The students in the experimental group were instructed with think pair share instructional strategy while the students in the control group were instructed with conventional, teacher-centered teaching. The students in the groups were taught by the same instructor. The main purpose of the course was to accustom the students with the scientific thinking skills which enhance their skills to examine, explore, analyze, and evaluate the principles of kinematics, Newton's Laws, energy conservation, impulse-momentum, and work. The application procedures of the think pair share instructional strategy and conventional, teacher-centered teaching were explained in detail as follows.

The procedures of the instructional strategy on a few sample activities before instruction were explained to the students in the EG. The procedure of think pair share instructional strategy in the experimental group could be listed as follows:

- The instructor initially performed short presentations on the notable points/concepts (e.g., force, velocity, acceleration, gravity, torque, momentum, energy, work, etc.) and fundamental principles (such as Newton's Laws of Motion, Conservation of Mechanical Energy, Conservation of Momentum (Linear and Angular), etc.) in each course instead of presenting the details covered in the textbook (10 minutes for each short presentation).

- The instructor presented a concept test or problem after each short presentation (1-2 minutes). Concept tests and/or problems based on Bloom's Taxonomy should especially be simple and comprehensible. These concept tests and problems were generally multiple choice questions. It was significant to give the students enough time to identify the key points of the concept tests or problems and to think about the students' answer. Open-ended questions might be asked to the students during the activity at times. More complicated questions might be given extra 1 or 2 minutes the students to think about answers.
- The students were given time to think about their solution concerning problems and concept tests silently. Then they recorded and wrote their answers individually (1-2 minutes).
- The students freely discussed and compared their individual responses and thoughts with their neighbor "partner/pair" before selecting a final answer. The students could arbitrarily be asked to study in the groups of 2 or 3. Finally they came to a conclusion on response of the question after the discussion. Meantime, the instructor determined misunderstanding on concepts, followed their solution ways, and listened carefully the discussions by walking around the pairs and observing to the class (1-2 minutes).
- The pairs' responses were voluntarily shared and discussed for finding a solution on the concept test or problem in the classroom. Then, the students revised their answers after the discussion. The instructor came across two circumstances for their answers as follows. a) If the majority of the answer was correct in the pairs, the instructor could summarize and examine the answer, if it was necessary, or this step could quickly be passed and moved on the other concept test or problem. b) If the majority of the answer was not correct, the students could discuss about the question with their partners under the instructor's guidance. Finally, the instructor provided a general feedback concerning correct answer. The students were allowed to record the final answer and solution (2-4 minutes).

Shortly, the instructor could give 10 minutes for *each short presentation* and s/he could give students the time between minimum 5 and maximum 10 minutes for *each concept test* and/or *problem* during the application of the instructional strategy. The application procedures may be changed to different disciplines and courses.

Conventional, Teacher-Centered Teaching

The same concept tests and problems were conducted to the control group students by means of conventional, teacher-centered teaching. The instructor performed the short presentations before each concept test or problem and the instructor asked the questions (concept tests and problems) to the control group students. They answered the questions in the classroom. Eventually, the instructor evaluated the students' responses. The instructor used the same amount of time as in the experimental group during learning and teaching.

Data Collection

The data of the research were collected with "Mechanics Baseline Test-MBT" and "Colorado Learning about Science Survey- CLASS" quantitatively. The data of the study was collected by pre-and post-test at the beginning and end of the research. Besides, the opinions of the voluntary students in the experimental group concerning think pair share instructional strategy were received qualitatively. These tools were thoroughly explained as follows.

Mechanics Baseline Test (MBT)

The MBT assessing students' understanding about classical mechanics (kinematics, general principles, specific forces, work, energy, and impulse-momentum) contained 26 five-option, multiple choice questions. The test was originally developed by Hestenes & Wells in 1992. The test was modified by conducting some statistical analysis (difficulty index, discrimination index etc.) by Cardamone, Abbott, Rayyan, Seaton, Pawl, & Pritchard (2012). The final test was consisted of 15 items concerning classical mechanics.

The validity and reliability of MBT were tested by using classical test theory. The analysis of validity and reliability of MBT were performed for Turkish version. The test initially was translated into Turkish and then reviewed in terms of reasonableness and appropriateness by three physics professors. Later the final version for the pilot study was applied to 127 voluntary engineering students who had taken the introductory calculus-based physics course. Finally the collected data was calculated statistically and the reliability coefficient of the pilot test was found to be 0.77 using the Kuder-Richardson 21 formula. The reliability coefficient is acceptance for an instrument of this type (Fraenkel & Wallen, 2009).

Colorado Learning about Science Survey (CLASS)

CLASS was developed to assess epistemological beliefs on physics and physics learning of students by Adams et al. 2006. The purpose of CLASS was to examine students' beliefs about physics and physics learning by using think pair share instructional strategies in the present study. The scale consists of 42 items with five-point Likert scale (i.e. "5=strongly agree", "4=agree", "3=neutral", "2= disagree", and "1=strongly disagree"). The scale was originally separated into eight factors according to statistical analysis results. These factors were named as "personal interest", "real world connection", "problem solving general", "problem solving confidence", "problem solving sophistication", "sense making/effort", "conceptual understanding", and "applied conceptual understanding". The analysis of validity and reliability of the scale were performed for Turkish version. First of all, the scale was translated into Turkish and then reviewed by Turkish language experts. Secondly, the final version for the pilot study was applied to 160 voluntary engineering students. Finally, the collected data was calculated statistically. "Exploratory Factor Analysis-EFA" using "Principal Component Analysis- PCA " with "Varimax Rotation- VR" was analyzed. Before starting the study, some items (4, 7, 9, 31, 33, and 41) were excluded in the scale. These items in the first version of the scale were not scored by Adams et al. 2006. The researcher removed indicated these items during the analysis. According to EFA, the exploration of the CLASS' validity revealed that "Bartlett's Test of Sphericity" was 1.333,43 (p<0.01), "Kaiser-Meyer-Olkin- KMO" value was 0.92 (KMO>0.60) and three factors were extracted with eigenvalues greater than 1.00. The sixteen items with "Factor Loadings" below 0.40 were excluded. Item loadings of selected 20 items ranged from 0.87 to 0.41. The factors accounted for 57% of total variance. 14 of these items have positive statements and 6 items have negative statements. Negative items were reversed while being coded.

These factors were named as PSG "problem solving general", CU "conceptual understanding" and SM/E "sense making/effort" by thinking the original scale. PSG consisted of seven positive items (e.g., "If I get stuck on a physics problem on my first try, I usually try to figure out a different way that works"). CU composed of two positive items and four negative items (e.g., "a significant problem in learning physics is being able to memorize all the information I need to know"). SM/E comprised five positive items and two negative items (e.g., "I am not satisfied until I understand why something works the way it does") although Adams et al. (2006) reported that PSG was eight items, SM/E was seven items, and CU was 6 items. The findings of both studies nearly adjusted on three factors including many items.

The Cronbach's alpha values of these factors were calculated as 0.79 for PSG, 0.79 for CU, and 0.74 for SM/E. The CLASS reliability was calculated to be 0.92. According to Hutcheson & Sofroniou (1999), these findings for an instrument showed that the calculated values were reasonable to use in low-risk study.

Qualitative Data Source

The students' opinion in the experimental group were documented by writing an anonymous essay on think pair share instructional strategy. Voluntary students (n=14) were asked to determine positive and negative aspects of the applied instructional strategy at the end of the application with the following question: "What do you think about the teaching of think pair share instructional strategy? Please state positive and negative aspects of think pair share instructional strategy." The students were given 10 minutes to write the essay.

Data Analysis

The students' responses to MBT and CLASS pre-test and post-test were calculated and analyzed. Descriptive statistics (M "means", and SD "standard deviations"), FG "Fractional Gain", and ANOVA "analysis of variance" for the collected data were calculated. Fractional gain equation developed by Hake (1998) was used to prevent the limitations in normal gain scores. Hake (1998) specially determined three gains. These gains are "high-gain" $g \geq 0.7$, "medium-gain" $0.7 > g \geq 0.3$, and finally "low-gain" $0.3 > g$.

$$(Fractional\ Gain\ );\ g = \frac{posttest\% - pretest\%}{maximum\ score\% - pretest\%}$$

An ANOVA was calculated to test the main treatment effect of the post-test means of the groups, after determining that the difference between the groups' pre-test means was not significant (p>0.05).

The voluntary students' opinions in the experimental group (14 of 35) were read, coded and classified by the researcher as being positive or negative. The majority of the students (approximately 80%) had positive opinions while 20% of the students held a negative opinion. The positive opinions focused usually on verbs (e.g., think, understand, like, enjoy, enhance, improve etc.). The students' negative opinions were combined with adjectives (e.g., redundant, time-consuming, nonsense, etc.)

Results and Discussion

The two way repeated measures ANOVA was conducted to identify any significant differences between the EG and the CG mean results on the post-test of MBT. Table 1 shows that the results from 2x2 (groups "EG and CG" x tests "pre-test and post-test") two way repeated measures ANOVA confirmed the performance differences of experimental and control groups.

Table 1. The results of ANOVA testing for differences between group' mean results

Repeated Measures ANOVA	F	df	p
Group	200.16	1,69	0.000
Test	734.81	1,69	0.000
Test x Group	156.86	1,69	0.000

The main treatment effect and interaction (test x group) between EG and CG were calculated to be statistically significant in favor of EG. Besides, the fractional gains (learning gain) of the groups were calculated. The learning gain of EG was found to be g_{EG}=0.67 "medium" and the learning gain of CG was calculated to be g_{CG}=0.25 "low". Figure 1 represents the interaction between the groups and the tests for MBT. The difference between the mean results of the students *before the instruction* revealed no statistically significant while the difference between the mean results of students *after the instruction* was found to be statistically significant in favor of the experimental group.

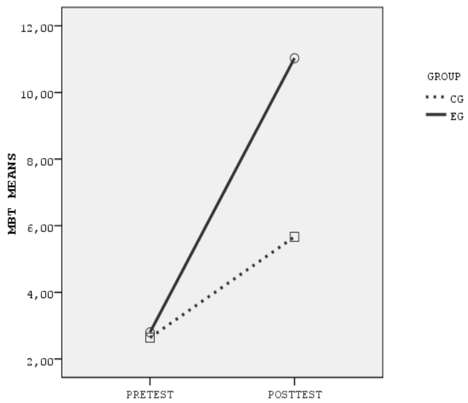


Figure1. The mean score differences between group mean results for MBT

The scores of the students in the control group were in the range of 4 and 8 while the scores of the students in the experimental group were in the range of 9 and 13 on the post-test. Figure 2 shows the minimum-maximum score distributions of the experimental and control groups on the post-test.

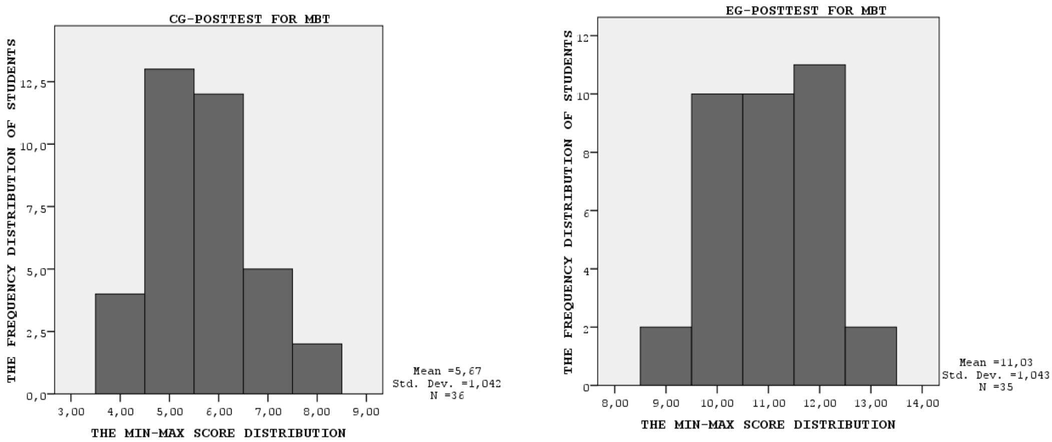


Figure 2. Min-max scores of students on MBT

Table 2. The results of ANOVA testing for differences between groups' score

		F	df	p
Group	CLASS	813.73	1,69	0.000
	PSG	190.43	1,69	0.000
	SM/E	643.20	1,69	0.000
	CU	461.57	1,69	0.000
Test	CLASS	1456.26	1,69	0.000
	PSG	351.14	1,69	0.000
	SM/E	849.93	1,69	0.000
	CU	599.14	1,69	0.000
Test x Group	CLASS	1353.41	1,69	0.000
	PSG	347.45	1,69	0.000
	SM/E	724.79	1,69	0.000
	CU	566.85	1,69	0.000

Table 2 shows the results of two way repeated measures ANOVA for the groups' CLASS score. The results were found to be statistically significant in favor of the experimental group. Figure 3 demonstrates the interaction between the groups and the sub-factors (PSG, SM/E and CU) of CLASS. The difference between the mean scores of the students *before the instruction* revealed no statistically significant while the difference between the mean scores of the students *after the instruction* was found to be statistically significant in favor of the experimental group.

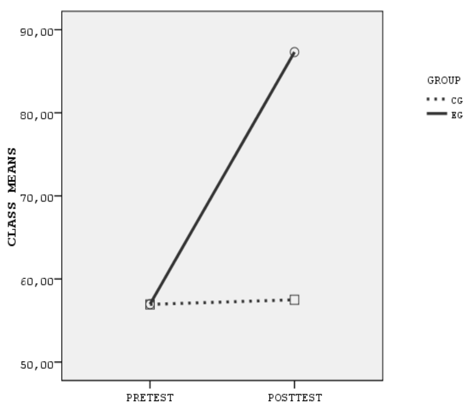
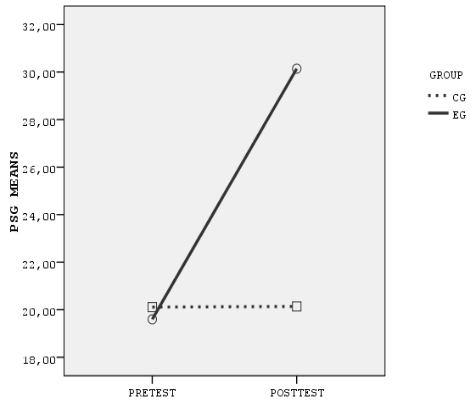


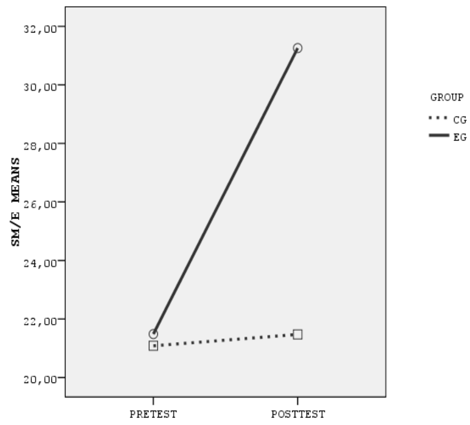
Figure 3. The differences between group mean scores for CLASS

Figure 4 represents the interaction between the groups and the sub-factors (PSG, SM/E, and CU) of CLASS. The difference between the mean scores of the students *before the instruction* for sub-factors (PSG, SM/E, and

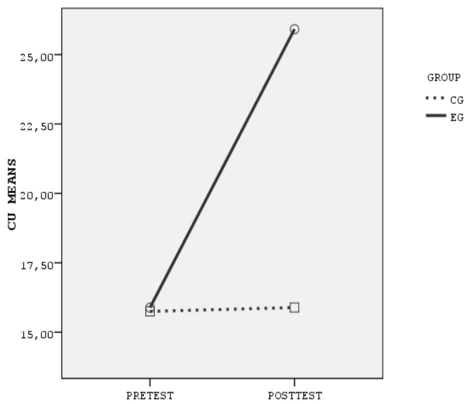
CU) revealed no statistically significant while the differences between the mean scores of the students *after the instruction* found to be statistically significant in favor of the experimental group.



(a)



(b)



(c)

Figure 4. The mean score differences between group mean scores for (a) PSG, (b)SM/E, and (c) CU factors

The scores of the students in the control group were in the range of 52 and 64 while the scores of the students in the experimental group were in the range of 84 and 92 on the post-test. Figure 5 shows the minimum-maximum score distributions of the experimental and control groups on the post-test.

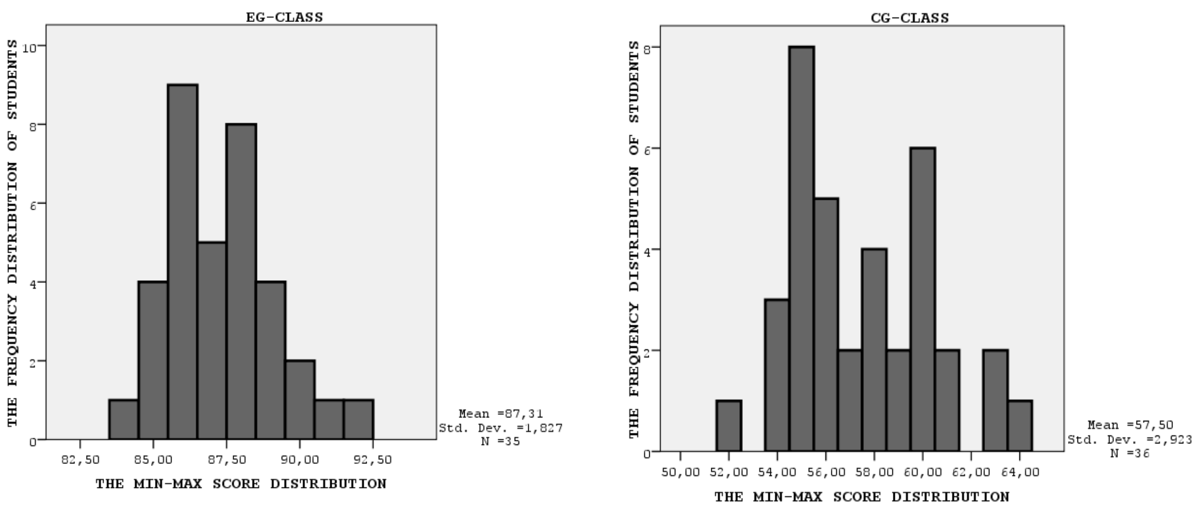


Figure 5. Min-max scores of students on CLASS

Students' Opinions about Think Pair Share Instructional Strategy

The general opinion of the students was collected with the student essays. Approximately 80% of the voluntary students represented their *positive opinions* about the teaching of think pair share instructional strategy as follows:

> Think pair share instructional strategy was really useful to comprehend relationships between new information and existing knowledge.
> They began to have interest in physics because they realized that they could understand fundamental concepts.
> They liked cooperative working during the implementation.
> They participated the courses more when working in pairs/partners.
> They began to think creatively.
> Think pair share instructional strategy enhanced self-confidence and responsibility of the students toward their own learning.
> They fostered positive attitude toward conceptual learning.

The *negative opinions* of the students (20%) were listed as follows:

> They could easily understand fundamental concepts. So, think pair share instructional strategy was time-consuming and unnecessary.
> They did not like to study in a group.
> They found the instructional strategy nonsense.

Conclusion

The present study revealed the positive effects of think pair share instructional strategy on students' conceptual learning about classical mechanics and the epistemological beliefs on physics and physics learning of the students relative to conventional, teacher centered teaching. The conceptual learning performance of the students instructed with think pair share instructional strategy was higher than the conceptual learning performance of the students instructed with conventional, teacher centered teaching. The factors affecting students performance during think pair share instructional strategy application could be summarized as follows: a) according to multiple-choice questions, the students meaningfully comprehended the fundamental principles and concepts of the subjects with the help of general feedback by the instructor, b) the students in the experimental group more participated in group discussion, c) they felt more comfortable when sharing their thoughts and ideas and they more communicated with pairs during discussions, d) think pair share instructional strategy proved to help the students in organizing the ideas and thoughts they had while working in the interactive classroom, e) the stress and embarrassment of the students in interactive learning environment diminished by cooperative working and finally f) the students took more responsibility toward their own learning between pairs. The researcher also observed that the students were more engaged in thinking, discussing and sharing in a group from in the beginning of the implementation to at the end of the implementation.

The results of the similar studies in the literature (Gok, 2014; Gok, 2015; Lasry, Mazur, & Watkins, 2008; Lasry, Charles, & Whittaker, 2016; Suppapittayaporn, Emarat, & Arayathanitkul, 2010) supported the results of the research. These studies reported that peer instruction like think pair share instructional strategy was effective on decision-making skills, meaningful learning, conceptual learning, quantitative and qualitative problem solving of the students. The conceptual understanding of the students instructed with peer instruction was evaluated with the help of the some standardized tests (Force Concept Inventory-FCI, Force and Motion Conceptual Evaluation-FMCE, Conceptual Survey of Electricity and Magnetism-CSEM etc.) (Fagen, Crouch, & Mazur, 2002; Gok, 2012; Kalman, Milner-Bolotin, & Antimirova, 2010; Lasry et al. 2008; Redish, Saul, & Steinberg, 1998; Suppapittayaporn et al. 2010). These studies revealed that the conceptual learning performance of the students instructed with peer instruction was higher than the conceptual learning performance of the students instructed with conventional, teacher-centered teaching methods. The findings of examined studies supported the findings of the present study. When the results of the research were generally evaluated, it could be said that the students in the experimental group correlated strong relationships between new information and existing knowledge, they interpreted taught fundamental concepts/principles, and they began to interrogate the concepts.

The epistemological beliefs on physics and physics learning of the students instructed with think pair share instructional strategy were more positive and higher than the epistemological beliefs on physics and physics learning of the students instructed with conventional, teacher centered teaching. The results in the literature (Adams et al. 2006; Crouch & Mazur, 2001; Gok, 2012; Kortemeyer, 2007; Lasry et al. 2016; Madsen et al. 2015; McDermott, 1991; Sharma et al. 2013; Stathopoulou & Vosniadou, 2007) supported the results of the research. These studies reported that peer instruction like think pair share instructional strategy was effective on epistemological beliefs on physics and physics learning of the students. The beliefs and attitudes of the students instructed with peer instruction was evaluated with the help of the some instruments (Maryland Physics Expectations-MPEX, Colorado Learning Attitudes about Science Survey-CLASS etc.). These studies revealed that the beliefs and attitudes of the students instructed with interactive engagement methods more enhanced than the beliefs and attitudes of the students instructed with conventional, teacher-centered teaching methods. The findings of examined studies supported the findings of the present study. Many studies revealed the positive correlations between the experience students' and inexperience students' epistemological beliefs and academic performances (Chu, Treagust, & Chandrasegaran, 2008; Domert et al. 2007; May & Etkina, 2002). When the results of the research were generally evaluated, it could be said that the students in the experimental group improved the view toward problem solving and conceptual understanding and began to make sense the learning materials based on fundamental principles/concepts. Besides the perception of the students having epistemological beliefs and attitudes on physics and physics learning changed with think pair share instructional strategy.

Recommendations

Some suggestions based on the findings of the results could be presented as follows:

There were a few challenges of think pair share instructional strategy in the application procedure. One of the challenges was to get the students to really be engaged during the discussion. The other drawback was the noise level during the discussion with each other of the students. Therefore some precautions on the mentioned challenges may be taken as follows: the instructor may walk around amongst pairs in the class during the activity and the instructor may encourage the students to focus on the concept tests and/or problems. Besides, the high digital technology called as "classroom response systems" for evaluating of the student results and managing time of the instructors may be effectively used in small and/or large groups.

References

Adams, W. K., Perkins, K. K., Podolefsky, N. S., Dubson, M., Finkelstein, N. D., & Wieman, C. E. (2006). A new instrument for measuring student beliefs about physics and leaning physics: The Colorado attitudes about science survey. *Physical Review Special Topics-Physics Education Research, 2 (010101)*, 1-14.

Allen, D., & Tanner, K. (2002). Approaches in cell biology teaching. *Cell Biology Education*, 1, 3-5.

Barkley, E. F., Cross, P. K., & Mayor, C. H. (2005). *Collaborative learning techniques: Handbook for college faculty*. San Francisco: Jossey-Bass.

Caballero, M. D, Greco, E. F., Murray, E. R., Bujak, K. R., Marr, M. J., Catrambone, R., Kohlmyer, M. A., & Schatz, M. F. (2012). Comparing large lecture mechanics curricula using the Force Concept Inventory: A five thousand student study. *American Journal of Physics, 80*(7), 638-644.

Cardamone, C. N., Abbott, J. E., Rayyan, S., Seaton, D. T., Pawl, A., & Pritchard, D. E. (2012). Item response theory analysis of the mechanics baseline test. *AIP Conference Proceedings, 1413*, 135-138.

Chu, H. E., Treagust, D. F., & Chandrasegaran, A. L. (2008). Naive students' conceptual development and beliefs: The need for multiple analyses to determine what contributes to student success in a university introductory physics course. *Research in Science Education, 38*(1), 111-125.

Cortright, R. N., Collins, H. L., & DiCarlo, S. E. (2005). Peer instruction enhanced meaningful learning: Ability to solve novel problems. *Advances in Physiology Education, 29*, 107- 111.

Crouch, C. H., & Mazur, E. (2001). Peer instruction: Ten years of experience and results. *American Journal of Physics, 69*, 970-977.

Domert, D., Airey, J., Linder, C., & Kung, R. F. (2007). An exploration of university physics students' epistemological mindsets towards the understanding of physics equations. *Nordic Studies in Science Education, 3*(1), 15-28.

Fagen, A. P., Crouch, C. H., & Mazur, E. (2002). Peer instruction: Results from a range of classroom. *The Physics Teacher, 40*, 206-209.

Fraenkel, J. R., & Wallen, N. E. (2009). *How to design and evaluate research in education* (7th ed). NY: McGraw-Hill.

Fraser, J. M., Timan, A. L., Miller, K., Dowd, J. E., Tucker, L., & Mazur, E. (2014). Teaching and physics education research: Bridging the gap. *Reports on Progress in Physics, 77*(3), 1-17.

Gok, T. (2012). The impact of peer instruction on college students' beliefs about physics and conceptual understanding of electricity and magnetism. *International Journal of Science and Mathematics Education, 10,* 417-436.

Gok, T. (2013). A comparison of students' performance, skill and confidence with peer instruction and formal education. *Journal of Baltic Science Education, 12*(6), 747-758.

Gok, T. (2014). Peer instruction in the physics classroom: Effects on gender difference performance, conceptual learning, and problem solving. *Journal of Baltic Science Education, 13*(6), 776-788.

Gok, T. (2015). An investigation of students' performance after peer instruction with stepwise problem-solving strategies. *International Journal of Science and Mathematics Education. 13*(3), 561-582.

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand student survey of mechanics test data for introductory physics courses. *American Journal of Physics, 66*, 64–74.

Hammer, D. (1994). Epistemological beliefs in introductory physics. *Cognition and Instruction, 12*(2), 151-183.

Hammer, D. (1995). Epistemological considerations in teaching introductory physics. Science Education, 79(4), 393-413.

Hestenes, D., & Wells, M. (1992). A mechanics baseline test. *The Physics Teacher, 30*, 159-166.

Hutcheson, G. D. & Sofroniou, N. (1999). *The multivariate social science scientist: Statistics using generalized linear models*. Thousand Oaks, CA: Sage.

Johnson. D. W., Johnson, R. T., & Smith, K. A. (1991). *Active learning: Cooperative learning in the college classroom*. Edina, MN: Interaction Book.

Johnson, D. W., & Johnson, R. T. (1999). Making cooperative learning work. *Theory into Practice*, *38*(2), 67-73.

Kalman, C. S., Milner-Bolotin, M., & Antimirova, T. (2010). Comparison of the effectiveness of collaborative groups and peer instruction in a large introductory physics course for science majors. *Canadian Journal of Physics, 88*, 325–332.

Kortemeyer, G. (2007). Correlations between student and discussion behavior, attitudes, and learning. *Physics Review Special Topics- Physics Education Research*, *3*(1), 1-8.

Kothiyal, A., Majumdar, R., Murthy, S., & Iyer, S. (2013). Effect of think-pair-share in a large CS1 class: 83% sustained engagement. *Proceedings of the Ninth Annual International ACM Conference on International Computing Education Research.* San Diego, CA: USA.

Kuo. E., & Wieman, C. E. (2016). Toward instructional design principles: Inducing Faraday's law with contrasting cases. *Physical Review Special Topics - Physics Education Research, 12*(010128), 1-14.

Lasry, N., Mazur, E., & Watkins, J. (2008). Peer instruction: From Harvard to the two-year college. *American Journal of Physics*, *76*(11), 1066-1069.

Lasry, N., Charles, E., & Whittaker, C. (2016). Effective variations of peer instruction: The effects of peer discussions, committing to an answer, and reaching a consensus. *American Journal of Physics, 84*(8), 639-645.

Lising, L., & Elby, A. (2005). The impact of epistemology on learning: A case study from introductory physics. *American Journal of Physics, 73*(4), 372-382.

Madsen, A., McKagan, S. B., & Sayre, E. C. (215). How physics instruction impacts students' beliefs about learning physics: A meta-analysis of 24 studies. *Physical Review Special Topics - Physics Education Research, 11*(010115), 1-19.

May, D. B., & Etkina, E. (2002). College physics students' epistemological self-reflection and its relationship to conceptual learning. *American Journal of Physics, 70*(12), 1240-1258.

Mazur. E. (1997). *Peer instruction: A user's manual*. Upper Saddle River, NJ: Prentice Hall.

McDermott, L. C. (1991). Millikan Lecture 1990: What we teach and what is learned-Closing the gap. *American Journal of Physics, 59*(4), 301-315.

McDermott, L. C. (1993). Guest comment: How we teach and how students learn-A mismatch? *American Journal of Physics, 61*(4), 129-298.

McDermott, L. C. (2001). Oersted medal lecture 2001: Physics education research- The key to student learning. *American Journal of Physics, 69* (11), 1127-1137.

Prahl, K. (2017). Best practices for the think-pair-share active-learning technique. *The American Biology Teacher, 79*(1), 3-8.

Puente, S. M. G., & Swagten, H. J. M. (2012). Designing learning environment to teach interactive quantum physics. *European Journal of Engineering Education, 37*(5), 448-457.

Raba, A. A. A. (2017). The influence of think-pair-share (TPS) on improving students' oral communication skills in EFL classrooms. *Creative Education, 8,* 12-23.
Redish, E. F., & Saul, J. M., & Steinberg, R. N. (1998). Student expectations in introductory physics. *American Journal of Physics, 66*(3), 212-224.
Redish, E. F. (2003). *Teaching physics with physics suite*. Hoboken, NJ: John Wiley & Sons.
Roth, W. M., & Roychoudhury, A. (1994). Physics students' epistemologies and views about knowing and learning. *Journal of Research in Science Teaching, 31*(1), 5-30.
Sampsel, A. (2013). Finding the effects of think-pair-share on student confidence and participation. *Honors Project, 28*.
Seung, E. (2013). The process of physics teaching assistants' pedagogical content knowledge development. *International Journal of Science and Mathematics Education, 11*, 1303-1326.
Sharma, S., Ahluwalia, P. K., & Sharma, S. K. (2013). Students' epistemological beliefs, expectations, and learning physics: An international comparison. *Physical Review Special Topics-Physics Education Research, 9*(010117), 1-13.
Silberman, M. (1996). *Active Learning: 101 strategies to teach any subject*. Needham Heights, MA: Allyn & Bacon.
Smith, M. K., Wood, W. B., Adams, W. K., Wieman, C., Knight, J. K., Guild, N., & Su, T. T. (2009). Why peer discussion improves student performance on in-class concept questions. *Science,* 323, 122-24.
Stathopoulou, C., & Vosniadou, S. (2007). Exploring the relationship between physics-related epistemological beliefs and physics understanding. *Contemporary Educational Psychology, 32,* 255-281.
Suppapittayaporn, D., Emarat, N., & Arayathanitkul, K. (2010). The effectiveness of peer instruction and structures inquiry on conceptual understanding of force and motion: A case study from Thailand. *Research in Science & Technological Education, 28* (1), 63-79.
Trent, K. S. (2013). *The effects of the peer instruction technique think-pair-share on students' performance in chemistry.* Unpublished master's thesis, Nicholls State University, Thibodaux, Louisiana.
Van Heuvelen, A. (1991). Learning to think like a physicist: A review of research-based instructional strategies. *American Journal of Physics, 59*(10), 891-897.

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Developing 21st Century Chemistry Learning through Designing Digital Games

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Abstract

The purpose of this study is to investigate the effect of Malaysian *Kimia* (Chemistry) Digital Games (MyKimDG) module on students' achievement and motivation in chemistry as well as 21st century skills. Chemistry education in Malaysia should put greater emphasis on combination of cognitive, sociocultural and motivational aspects to ensure that students are well-equipped with knowledge, skills and values relevant to the new global economy. Previous studies have reported that digital game-based learning (DGBL) provides opportunities for increasing students' motivation in learning while enhancing their academic achievement and 21st century skills. Based on the DGBL approach as well as constructivist-constructionist learning theories, MyKimDG was developed as a mechanism for achieving the desired goals. In this study, students were provided opportunities to take on the role of game designers, developing digital games while learning chemistry. This study employed quasi-experimental with non-equivalent control group pretest-posttest control group design. Subjects were composed of 138 secondary students. Results showed that the treatment group outperformed the control group in the chemistry achievement test. In addition, students' self-efficacy and high productivity scores improved significantly between pretest and posttest for treatment group. The findings imply that the inclusion of student as game designer approach in chemistry learning is able to help students develop an in-depth knowledge on chemistry and foster their 21st century skills as well as increase students' motivation in chemistry.

Introduction

Science, technology and innovation (STI) has been recognized as a vital driver of economic and social development (UNCTAD, 2017). People are key for the creation, diffusion and use of knowledge through STI (OECD, 2016). For science and technology innovators it is important to master chemistry knowledge because chemistry is essential for comprehending most of the fields of science, technology and engineering (Balaban & Klein, 2006). Indeed, chemistry is often called the central science (Brown, LeMay, Bursten, Murphy, & Woodward, 2011; Chang, 2007). Apart from knowledge, innovation in the 21st century requires a new range of skills known as 21st century skills. For instance, effective communication and collaboration problem solving skills are crucial for success in today's complex world. Increasing levels of complexity require expertise communicate effectively and working together to solve problems or create novel products. For that reason, chemistry education in the 21st century should be given simultaneously on enhancing students' knowledge acquisition as well as nurturing of 21st century skills to produce students who are capable of generating science and technology innovation. Meanwhile, students must be highly motivated so that the learning becomes more efficient. According to Deci, Vallerand, Pelletier and Ryan (1991), the acquisition of knowledge is insufficient. At the same time, students also need to be passionate about learning and engage voluntarily in the learning.

Unfortunately, studies (e.g. Iksan, Halim, & Osman, 2006; Osman, Iksan, & Halim, 2007) showed that Malaysian students had a moderate level of motivation in science. The studies also revealed that students' motivation in science decreased with increasing of educational stages. Furthermore, Malaysian students' achievement in chemistry is also not encouraging. Based on the performance analysis of Malaysian Certificate of Education (SPM) Chemistry from 2010 to 2013 revealed that approximately 40 percent of the candidates were unable to master chemistry concepts to earn good grades. Chemistry is usually perceived as a difficult and unpopular subject due to the abstract nature of chemical concepts. Studies (e.g. Lay & Osman, 2015; Lee & Osman, 2014) revealed that the Salt chapter is considered the toughest chapter in the Malaysian Chemistry Curriculum. The problem which causes difficulty in the Salt chapter is that students lack of understanding of the reactions occurred (Tan, Goh, Chia, & Treagust, 2002). In the chapter of Salt, chemical reactions and physical changes involved include solubility, precipitation, displacement, thermal decomposition and acid-base reaction. In term of 21st century skills, studies (e.g. Amin, Jaffar, Hood, Saad, & Amin, 2013; Ariffin, 2005; Hew & Leong, 2011; Sukor, Osman, & Abdullah, 2010) have reported that the 21st century skills of Malaysian students are unsatisfactory. It is therefore not surprising that the results of PISA 2012 assessment on creative problem-solving (OECD, 2014) showed Malaysian student performance ranked 39th out of 44 participating countries.

Thus, 21st century chemistry education in Malaysia should put greater emphasis on combination of cognitive, sociocultural and motivational aspects to ensure that students are well-equipped with knowledge, skills and values relevant to the new global economy. In this case, a change in chemistry instructional approaches is critical. This is especially more crucial when educating today's students who are 'digital wisdom' (Prensky, 2012). The teaching and learning approaches must befit the needs of these digital natives and subsequently achieve the desired aspiration (i.e. promote students' conceptual understanding and motivation in chemistry) while provide opportunities for 21st century skills development.

Digital Games and Chemistry Learning

One approach suggested by researchers to educate the digital native generation is digital game-based learning (DGBL). Nowadays, DGBL is gaining popularity parallel with their popular reputation among students (Osman & Bakar, 2013). In general, the studies on DGBL were carried out through two approaches, namely (i) student as game consumer or player, and (ii) student as game designer. In the first approach, the students were involved in playing commercial digital games in the market or educational digital games developed by educators. However, there are many obstacles to implementing the student as game consumer approach. For instance, the contents of commercial digital games are inaccurate or incomplete as they are not designed to teach (Van Eck, 2006); and the development of educational digital games is time-consuming because effective learning strategies need to be developed as an integrated part of professional educational digital games (Hwang, Sung, Hung, Yang, & Huang, 2013). One alternative of DGBL approach that has been proposed by some scholars (Jung & Park, 2009; Kafai, 1996; Osman & Bakar, 2013; Papert, 1998) is for students to design their own digital games. Many studies have reported that this approach provide opportunities for students to explore ideas according to their own interests (Kafai & Ching, 1996); become active participants and problem solvers, engage in social interaction by sharing their designs and helping each other and take ownership of their own learning (Baytak & Land, 2010). In addition, the student as game designer approach is a better way to increase students' motivation and deep learning compared to the student as game consumer approach (Vos, van der Meijden, & Denessen, 2011). According to them, this might be due to constructing a game demands more student activity than playing a game, which is to some extent a more passive learning activity. Scholars, such as Lim (2008) and Prensky (2008), also recognized the potential of this approach in improving student motivation and engagement. Therefore, an innovation has been initiated to take advantage of the student as game designer approach to support the acquisition of chemical concepts and 21st century skills as well as increase students' motivation in chemistry. A module known as Malaysia *Kimia* (Chemistry) Digital Game, MyKimDG, has been developed in order to assist students in the learning of the Salt chapter and achieve the desired goals.

MyKimDG Module

The MyKimDG was developed based on Kemp Instructional Design Model (Morrison, Ross, Kalman, & Kemp, 2013). Principles derived from constructivist and constructionist learning theories play an important role in guiding MyKimDG development. The authors identified six guiding principles that should be incorporated in MyKimDG:

- Knowledge construction: Student constructs new understanding pursuant to his/her existing knowledge (Piaget, 1977).
- Collaboration: Peer collaboration may trigger cognitive conflict and this may result in reconstruction of ideas (Vygotsky, 1978).
- Exploration: Understanding is lifted when students discover new knowledge themselves (Bruner, 1962).
- Learning through designing: Learning can be enhanced if students are involved in design projects (Papert, 1991).
- Motivation: Motivation is recognized as a factor affecting conceptual change and reconstruction of ideas (Palmer, 2005).

- Technological literacy: Leverage contemporary technologies efficiently and effectively to communicate, collaborate, solve problems, accomplish tasks and as construction material (Papert, 1999). However, the focus is not on the technology alone, but on the promoting technological literacy.

Based on these principles, activities in MyKimDG were designed so that students engage in discovery activities through teamwork. In addition, they were required to design digital games using ICT to teach their peers who faced problems in the learning of the chemical concept. To assist students in carrying out discovery activities and digital game design projects, they were guided to go through the IDPCR phases (Inquiry-Discover-Produce-Communicate-Review) (see Figure 1). The IDPCR phases are illustrated below with reference to a chemistry unit which involved precipitation reaction. To assist students understand why precipitation reaction used in the preparation of insoluble salt, they were engaged in discovery activity. Figure 2 shows the Inquiry and Discover phases of the discovery activity. To extend students' understanding about the observed phenomenon (i.e. precipitation reaction), they were given tasks to design digital games using ICT to teach their peers who faced problems in the learning of the chemical concept. The game-design activities are presented in Figure 3. Students were engaged in designing *PowerPoint* games to represent the phenomenon at the sub-microscopic level. It was expected that the learning environment created by implementation of MyKimDG would improve students' conceptual understanding, motivation in chemistry and 21st century skills. Apart from that, it was expected that the acronym IDPCR could help students remember the five important domains of 21st century skills, i.e. **I**nventive thinking, **D**igital-age literacy, high **P**roductivity, effective **C**ommunication and spiritual values (*nilai ke**R**ohanian*).

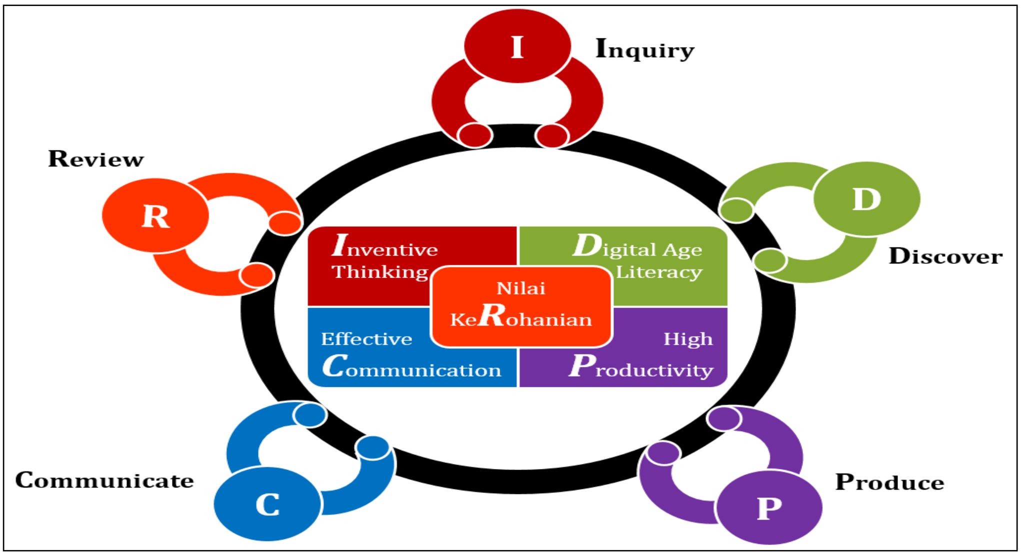

Figure 1. IDPCR

Inquiry - Cuba fikirkan

INQUIRY-DISCOVERY In order to prepare lead(II) sulphate, Ahmad suggested two reactions. Which reaction is more suitable for preparing lead(II) sulphate?

	Reaction	*Observation*	*Chemical equation*
A	Lead(II) nitrate solution + potassium sulphate solution		
B	Excess solid lead(II) carbonate + dilute sulphuric acid		

Discover - Mari kita meneroka

How can Ahmad obtain the lead(II) sulphate formed from the mixture in Reaction **A** or **B**?

(a) Draw the set-up of the apparatus involved.
(b) In your opinion, which reaction is more appropriate in preparing insoluble salts such as lead(II) sulphate? Explain your answer.
(c) Plan and carry out investigation to test your hypothesis.
(d) Make a conclusion about the reaction used to prepare insoluble salts.
(e) Share your findings with other groups.
(f) Explain the strategy used in this activity.

Figure 2. Discovery activities in MyKimDG

AKTIVITI 8.7 MyKimDG

1. Students play a game related to the precipitation reaction.
2. Students are asked to differentiate between a good game and a bad game.
3. Students are asked to improve the game they played to make it more educational and entertaining following the IDPCR phases, in order to help their peers who face difficulty in learning the concept.
   3.1 **Inquiry:** Students brainstorm the design of the game in groups and select a favourite design from their brainstorming session and sketch their chosen design.
   3.2 **Discover:** Students create their designs using *PowerPoint*. Students are encouraged to test frequently and think critically about their designs, and rebuild as needed.
   3.3 **Produce:** Students produce their *PowerPoint* games based on improvements suggested through testing.
   3.4 **Communicate:** Students share their designs and *PowerPoint* games and get input from other groups.
   3.5 **Review:** Students describe the key strengths and weaknesses of their designs and *PowerPoint* games. Students create their own *PowerPoint* game in groups that incorporates the best aspects of all the designs.

Figure 3. Game-design activities in MyKimDG

Objective of Study

The authors developed the MyKimDG and carried out the study for several objectives as listed below:

- Identify the effectiveness of MyKimDG on students' achievement in Salt chapter.
- Identify the effectiveness of MyKimDG on students' 21st century skills.
- Identify the effectiveness of MyKimDG on students' motivation in chemistry.

Method

The study is a quasi-experimental study with a non-equivalent control group pretest-posttest design. There were two intervention groups: the treatment group and the control group. Students in the treatment group learned the Salt chapter using the MyKimDG developed by the authors. On the other hand, the control group students were instructed in conventional method using learning materials (i.e. text book and practical book) mandated by the national curriculum for Chemistry.

Subjects of Study

A total of 138 (56 males and 82 females) Form Four students (16 years old) from four secondary schools in one of the districts in Malaysia were involved in the study. Two schools were randomly selected as the treatment group and another two schools were assigned as the control group. Three classes with some similar characteristics (e.g. the ratio of male and female students; the experience of the Chemistry teacher who taught the class) were chosen from each group. There were 24 males and 35 females in the control group, and 32 males and 47 females in the treatment group. Both groups were taught by chemistry teachers who have more than five years of experience in teaching chemistry. The students then completed the pre-test to ensure that students from the both groups were homogenous in terms of existing knowledge in the Salt chapter, 21st century skills and motivation in chemistry. Independent-samples t-test results (see Table 1) showed that both groups had no significant difference in prior knowledge in the Salt chapter, 21st century skills and motivation in chemistry.

Table 1. Descriptive statistics and results of independent-samples t-test for pretest

Test	Group	*N*	*M*	*SD*	*t*	Sig.(2-tailed)
Achievement test	Control	59	10.65	4.73	-0.34	0.732
	Treatment	79	10.93	4.70		
21st century skills	Control	59	3.76	0.28	-0.66	0.510
	Treatment	79	3.79	0.29		
Motivation in chemistry	Control	59	3.71	0.24	1.24	0.217
	Treatment	79	3.65	0.27		

$\alpha = 0.05$

Instruments of Study

Achievement Test

The achievement tests were administered in the form of a pretest and posttest before and after the intervention. Items in the pretest and the posttest were equivalent in terms of the level of Bloom's taxonomy and the concepts tested. The pretest was used to identify students' existing knowledge before interventions. The posttest scores were used to compare the effectiveness of interventions (i.e. conventional method and MyKimDG) in increasing students' achievement in the Salt chapter.

SMTSL Questionnaire

This questionnaire is a Likert scale questionnaire. The original version of the questionnaire, Students' Motivation towards Science Learning (SMTSL), was developed by Tuan, Chin and Shieh (2005). The word 'science' in the original SMTSL was substituted for the word 'chemistry'. There are six domains of motivation involved: self-efficacy, active learning strategies, science learning value, performance goal, achievement goal, and learning environment stimulation. The Cronbach's alpha of each domain ranged from 0.72 to 0.81. The overall Cronbach's alpha of the SMTSL was 0.85. The questionnaire was given to the samples before and after the interventions. The pretest was used to measure students' existing motivation level before interventions. The pretest and posttest scores were used to evaluate the impact of the interventions in increasing students' motivation in chemistry.

M-21CSI Questionnaire

This questionnaire is a Likert scale questionnaire developed by Soh, Osman, and Arsad (2012). There are five domains of 21st century skills involved: digital age literacy, inventive thinking, effective communication, high productivity, and spiritual values. The five domains of 21^{st} century skills were identified by Osman and Marimuthu (2010). The Cronbach's alpha of each domains ranged from 0.80 to 0.93. The overall Cronbach's alpha of the M-21CSI was 0.97. The questionnaire was given to the samples before and after the interventions. The pretest was used to measure students' existing 21^{st} century skills level before interventions. The pretest and posttest scores were used to evaluate the impact of the interventions in increasing students' 21^{st} century skills level.

Results

Students' Achievement in the Salt Chapter

Data screening was carried out prior to statistical procedure. No missing data or outliers were found in the control group. On the other hand, two samples of treatment group in the original sample had missing data on either pre or post achievement test. Five outliers were detected on pretest, posttest or both among the sample in the treatment group. After deletion of cases with missing data and outliers, the numbers of samples in treatment group reduced to 72. Assumption regarding the normality of sampling was met for both pre and posttest scores of control and treatment groups.

T-tests were conducted to evaluate the impact of the interventions on students' scores in the achievement test. Table 2 shows the descriptive statistics and results of the independent-samples t-test for achievement pretest and posttest. The results showed that there was no significant difference in pre-test scores for the treatment (M = 11.20, SD = 4.75) and the control groups (M = 10.65, SD = 4.73); $t(129) = -0.67$, $p = 0.507$. However, there was a statistically significant difference in posttest scores for the treatment (M = 37.15, SD = 12.70) and the control groups (M = 19.29, SD = 10.99); $t(129) = -8.50$, $p < 0.001$.

The magnitude of the differences in the means (mean difference = 17.86, 95% Cl: 13.70 to 22.01) was large (eta squared = 0.36). Descriptive statistics showed that students who learned the Salt chapter with the MyKimDG module were achieving higher results compared with the control groups who learned the same chapter using the conventional method. Hence, the MyKimDG developed in the study was proven to have ability to help students produce better content achievement in the Salt chapter. Figure 4 shows the changes of achievement test scores across time point by intervention groups.

Table 2. Descriptive statistics and results of independent-samples t-test for achievement pretest and posttest

Test	Group	*N*	*M*	*SD*	*t*	Sig.(2-tailed)
Pre	Control	59	10.65	4.73	-0.67	0.507
	Treatment	72	11.20	4.75		
Post	Control	59	19.29	10.99	-8.50	0.000
	Treatment	72	37.15	12.70		

α = 0.05

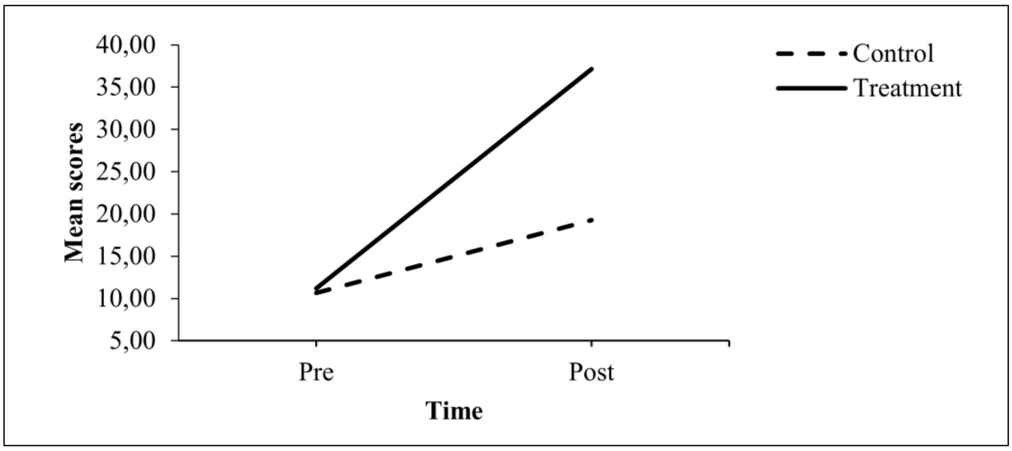

Figure 4. Achievement test scores across time point by intervention group

Students' 21st Century Skills

Table 3 shows the descriptive statistics for the five domains of 21st century skills by group and time point.

Table 3. Descriptive statistics for the five domains of 21st century skills by group and time point

Domain	Group	*N*	Pretest		Posttest	
			M	*SD*	*M*	*SD*
Digital age literacy	Control	59	3.68	0.31	3.65	0.31
	Treatment	79	3.64	0.34	3.72	0.25
Inventive thinking	Control	59	3.72	0.33	3.76	0.33
	Treatment	79	3.78	0.36	3.87	0.32
Effective communication	Control	59	3.70	0.37	3.88	0.34
	Treatment	79	3.86	0.39	3.90	0.40
High productivity	Control	59	3.60	0.38	3.63	0.36
	Treatment	79	3.55	0.33	3.77	0.36
Spiritual value	Control	59	4.08	0.48	4.15	0.41
	Treatment	79	4.11	0.48	4.22	0.47

A doubly-multivariate analysis of variance was performed to investigate the group differences in 21st century skills at two time points (pre and post interventions). No data were missing. Preliminary assumption testing for normality, univariate and multivariate outliers, homogeneity of variance-covariance matrices, linearity and multicollinearity showed that no violations were found. Results (Table 4) showed that the interaction between group and time is statistical significant for high productivity [$F(1, 136) = 5.375$, $p = 0.022$; partial eta squared = 0.038]. Figure 5 shows the changes of high productivity scores across time point by intervention groups.

Table 4. Univariate test for each domain of 21st century skills

Effect	Domains	*SS*	*df*	*MS*	*F*	Sig.	Partial η^2
Time*Group	Digital age literacy	0.192	1	0.192	2.497	0.116	0.018
	Inventive thinking	0.034	1	0.034	0.342	0.560	0.003
	Effective communication	0.258	1	0.258	2.246	0.136	0.016
	High productivity	0.586	1	0.586	5.375	0.022	0.038
	Spiritual value	0.040	1	0.040	0.178	0.674	0.001

α = 0.05

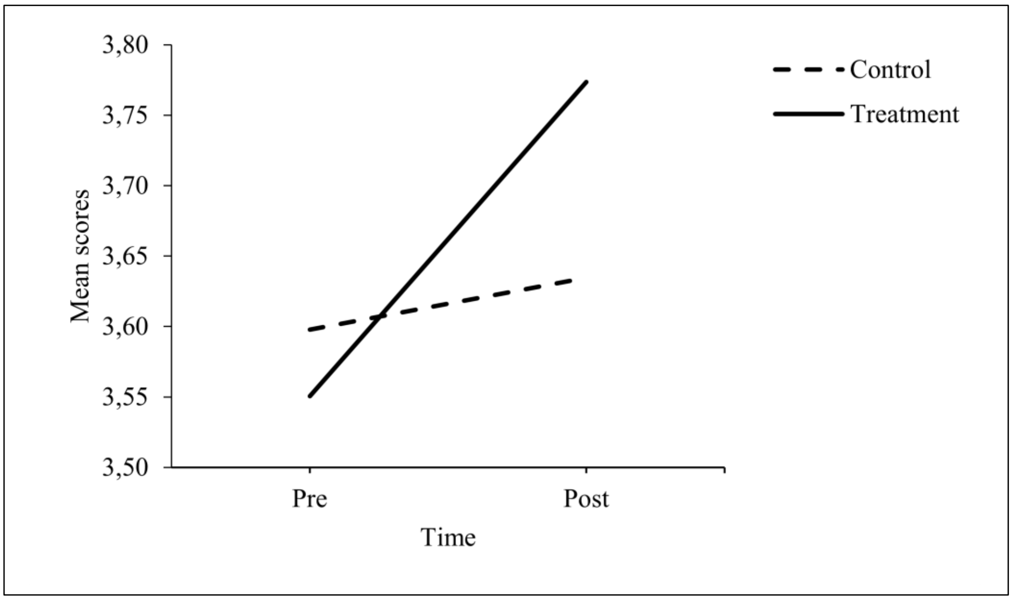

Figure 5. High productivity scores across time point by intervention group

As shown in Table 5, further analyses of the interaction between group and time for high productivity scores revealed that there was no significant differences between groups at pretest [$t(136) = 0.782$, $p = 0.436$], but there was a significant differences between groups at posttest [$t(136) = -2.266$, $p = 0.025$]. An inspection of the posttest mean scores indicated that treatment group reported slightly higher levels of high productivity (M = 3.77, SD = 0.36) than control group (M = 3.63, SD = 0.36). The magnitude of the differences in the means (mean difference = 0.14, 95% Cl: 0.02 to 0.26) was small (eta squared = 0.04).

Table 5. Descriptive statistics and results of independent-samples t-test for high productivity

Time	Group	*N*	*M*	*SD*	*t*	Sig. (2-tailed)
Pre	Control	59	3.60	0.38	0.782	0.436
	Treatment	79	3.55	0.33		
Post	Control	59	3.63	0.36	-2.266	0.025
	Treatment	79	3.77	0.36		

$\alpha = 0.05$

Further analyses as presented in Table 6 also showed that the high productivity scores improved significantly between pretest and posttest for treatment group, $t(136) = -3.949$, $p < 0.001$. These findings showed that students who used the MyKimDG were achieving higher in high productivity skill compared with the control groups who were taught in conventional method. Hence, the MyKimDG was proven to have the ability to increase students' high productivity skills.

Table 6. Descriptive statistics and results of paired-samples t-test for high productivity

Group	Test	*N*	*M*	*SD*	*t*	Sig. (2-tailed)
Control	Pre	59	3.60	0.38	-0.680	0.499
	Post	59	3.63	0.36		
Treatment	Pre	79	3.55	0.33	-3.949	0.000
	Post	79	3.77	0.36		

$\alpha = 0.05$

Students' Motivation in Chemistry

Descriptive statistics for the six domains of motivation by group and time point are in Table 7.

Table 7. Descriptive statistics for the six domains of motivation in chemistry by group and time point

Domain	Group	*N*	Pretest		Posttest	
			M	*SD*	*M*	*SD*
Self-efficacy	Control	59	3.55	0.57	3.34	0.67
	Treatment	79	3.44	0.50	3.66	0.50
Active learning strategies	Control	59	3.97	0.33	3.92	0.45
	Treatment	79	3.86	0.38	3.92	0.40
Science learning value	Control	59	3.99	0.40	3.96	0.52
	Treatment	79	4.01	0.39	4.17	0.45
Performance goal	Control	59	2.86	0.78	2.96	0.67
	Treatment	79	2.83	0.55	3.01	0.80
Achievement goal	Control	59	4.01	0.42	4.05	0.59
	Treatment	79	4.05	0.50	4.14	0.44
Learning environment stimulation	Control	59	3.87	0.41	3.82	0.45
	Treatment	79	3.72	0.45	3.84	0.43

A doubly-multivariate analysis of variance was performed to investigate the group differences in motivation at two time points (pre and post interventions). No data were missing. Preliminary assumption testing for normality, univariate and multivariate outliers, homogeneity of variance-covariance matrices, linearity and multicollinearity showed that no violations were found. Results (Table 8) showed that the interaction between group and time is statistical significant for self-efficacy [$F(1, 136) = 10.96$, $p = 0.001$; partial eta squared = 0.075]. Figure 6 shows the changes of self-efficacy scores across time point by intervention groups.

Table 8. Univariate tests for each domain of motivation

Effect	Domain	*SS*	*df*	*MS*	*F*	Sig.	Partial η^2
Time*	Self-efficacy	2.98	1	2.98	10.96	0.001	0.075
Group	Active learning strategies	0.20	1	0.20	1.35	0.248	0.010
	Science learning value	0.60	1	0.60	3.43	0.066	0.025
	Performance goal	0.11	1	0.11	0.25	0.618	0.002
	Achievement goal	0.05	1	0.05	0.22	0.638	0.002
	Learning environment stimulation	0.51	1	0.51	2.51	0.116	0.018

$\alpha = 0.05$

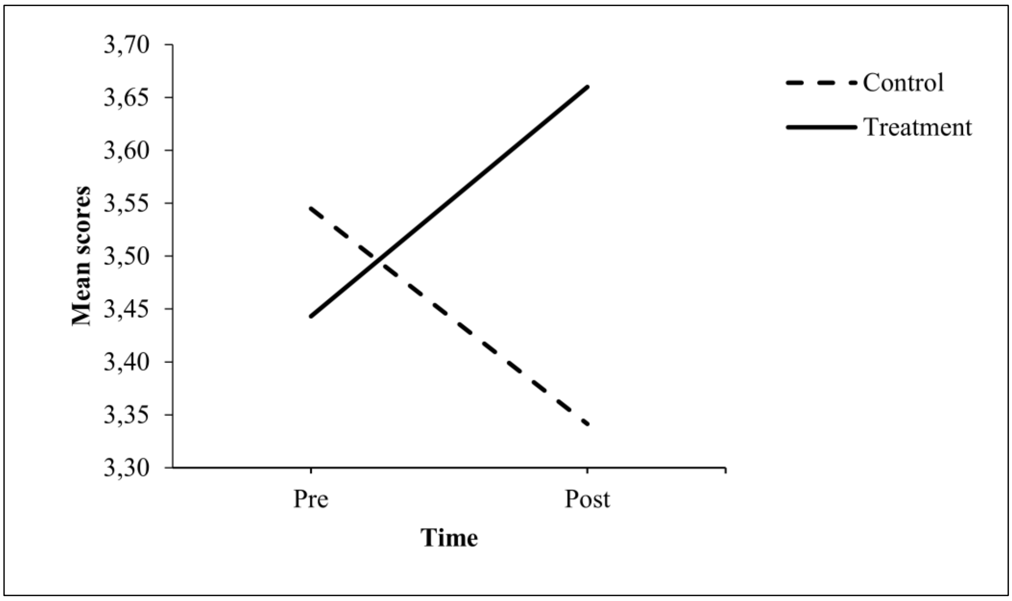

Figure 6. Self-efficacy scores across time point by intervention groups

As shown in Table 9, further analyses of the interaction between group and time for self-efficacy scores revealed that there was no significant differences between groups at pretest [$t(136) = 1.12$, $p = 0.265$], but there was a significant differences between groups at posttest [$t(136) = -3.06$, $p = 0.003$]. An inspection of the posttest mean scores indicated that treatment group reported higher levels of self-efficacy ($M = 3.66$, $SD = 0.50$) than control group (*M* = 3.34, *SD* = 0.67). The magnitude of the differences in the means (mean difference = 0.32, 95% Cl: 0.11 to 0.53) was moderate (eta squared = 0.06).

Table 9. Descriptive statistics and results of independent-samples t-test for self-efficacy

Test	Group	*N*	*M*	*SD*	*t*	Sig. (2-tailed)
Pre	Control	59	3.55	0.57	1.12	0.265
	Treatment	79	3.44	0.50		
Post	Control	59	3.34	0.67	-3.06	0.003
	Treatment	79	3.66	0.50		

$\alpha = 0.05$

Further analyses as presented in Table 10 also showed that the self-efficacy scores improved significantly between pretest and posttest for treatment group, $t(136) = -3.40$, $p = 0.001$. These findings showed that the MyKimDG was proven to have the ability to increase students' self-efficacy.

Table 10. Descriptive statistics and results of paired-samples t-test for self-efficacy

Group	Test	*N*	*M*	*SD*	*t*	Sig. (2-tailed)
Control	Pre	59	3.55	0.57	1.70	0.095
	Post	59	3.34	0.67		
Treatment	Pre	79	3.44	0.50	-3.40	0.001
	Post	79	3.66	0.50		

$\alpha = 0.05$

Discussion

The findings suggested that learning through MyKimDG was more effective than the conventional method at supporting a higher achievement in the Salt chapter, 21st century skills and motivation in chemistry. In particular, it is proven that MyKimDG may improve students' high productivity skills and self-efficacy. The high productivity skill in this study consists of three dimensions: (i) prioritize, plan, and manage for results, (ii) effective use of real-world tools, and (iii) ability to produce relevant and high-quality products. Self-efficacy refers to the people's beliefs about their ability in producing designated levels of performance (Bandura, 1997).

Generally, the practice in Malaysian science classroom is very much bounded by conventional method that generally focus on knowing content in the learning materials for summative assessment purpose (Ministry of Education Malaysia, 2013). In some science classroom, teachers' practices do not reflect the real constructivist learning approach that required by the Malaysian Science Curriculum (Sim & Arshad, 2015; Tan & Arshad, 2014). Teachers normally begin teaching the Salt chapter by explaining the facts in the text book before students engage in experiments. Afterwards, students followed the procedures in practical book to carry out experiments. Teachers then led students to draw conclusions. In this process, students were not given opportunities to discover ideas or concepts for themselves nor think about the chemical concept behind a chemical procedure. In this partially student-centered approach, rote memorization was generally still dominant. As a result, students did not understand the procedures meaningfully. Therefore, students were unable to apply the memorized facts to complete assignments that involve higher order thinking skill – synthesizing salts and qualitative analysis of salts.

Contrary to the conventional method, MyKimDG created learning environment that allows students to work together to learn and discover ideas or concepts (see Figure 2). Activities in MyKimDG were designed to engage students in communicating their ideas and making decisions based on the group's consensus. They were also engaged in design justification and argumentation (see Figure 3). In these processes, students also listen to input from peers and defend their ideas. Peer's input may trigger cognitive conflict and this may result in reconstruction of existing ideas, and hence towards deeper level of understanding. Collaborative and argument-driven classroom were reported to be more successful than the traditional classroom for improving academic achievement (Balci & Yenice, 2016; Capar & Tarim, 2015; Demircioglu & Ucar, 2015). Besides, students were given opportunities to visualize the concepts in the sub-microscopic level, and explained or represented the macroscopic experience at the sub-microscopic and symbolic levels. The triplet relationship is the key model used in chemical education (Gilbert & Treagust, 2009) to increase students' conceptual understanding. Figure 7 shows example of dissolution model created by students. Therefore, students in treatment group were more likely to demonstrate better improvement in the Salt chapter then the control group.

In MyKimDG, students were also given opportunities to engage in collaborative *PowerPoint* Game modifying and designing projects. They were required to carefully plan, utilize time and 21st century tools and resources toward the goal – creating *PowerPoint* game to help their peers who face difficulty in learning a particular chemical concept. The task were challenging but achievable with reasonable efforts and scaffolding. To help students in developing the *PowerPoint* game designing skills, the development phases proposed by Rieber, Barbour, Thomas and Rauscher (2008) was used as a guide in MyKimDG (see Figure 3). First, students played an existing game. Afterwards, they were asked to improve the game they played to make it more educational and entertaining. Students then designed their own digital game collaboratively. At the final stage, they were asked to improve and produce higher quality *PowerPoint* games that incorporate the best aspects of other groups' designs. The findings showed that this approach was able to increase students' perceived self-efficacy because students were given opportunities to experience successes. Repeated mastery experiences had led to a greater sense of competence (or self-efficacy). The findings also showed that this approach was able to increase students' high productivity skill because students were able to immerse themselves in the real-world practice. Besides, the IDPCR phases in MyKimDG can provide students a foundation in engineering design. As students become more fluent with the phases, they are expected to develop more complex projects. Students are also expected to practice the phases in everyday life and in the workplace, and hence, develop not only STEM-literate workforce, but also STEM-literate citizenry.

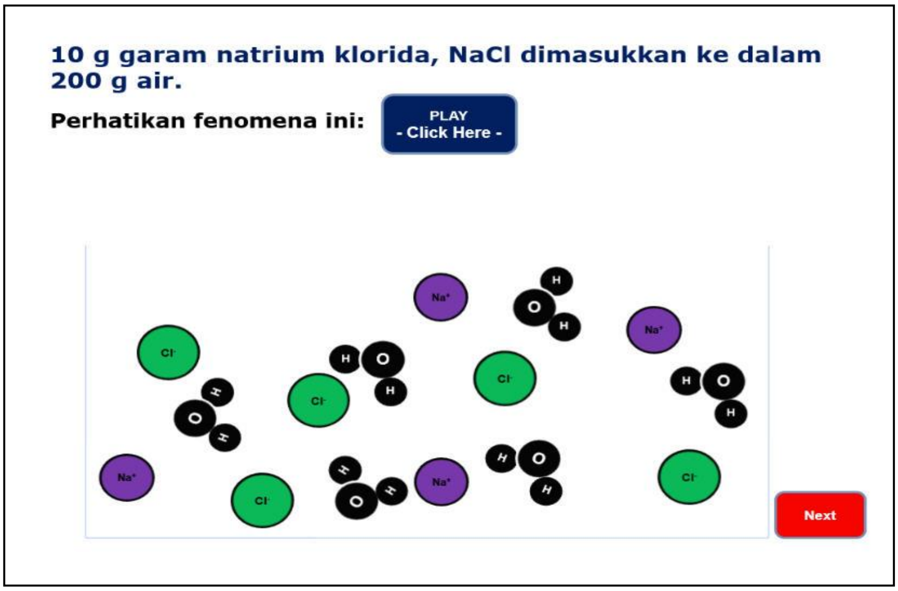

Figure 7. Example of dissolution model created by students

For other domains of 21st century skills (digital age literacy, inventive thinking, effective communication, and spiritual value), descriptive statistics (see Table 3) presented that students in the treatment group showed improvement in all these domains, even though not statistically significant. On the other hand, the application of conventional method was able to increase three domains of 21st century skills (inventive thinking, effective communication, and spiritual value), but there was a decrement in digital age literacy scores after intervention. Similarly, based on descriptive statistics (see Table 7), students in the treatment group showed improvement in other five domains of motivation (active learning strategies, science learning value, performance goal, achievement goal, and learning environment stimulation) even though not statistically significant.

By contrast, the application of conventional method was able to increase two domains of motivation (i.e. performance goal and achievement goal). The active learning strategies, science learning value, and learning environment stimulation scores for control group decreased after intervention. The results indicated that the use of the MyKimDG has the potential to further foster 21st century skills and motivation in chemistry compared to the conventional method. In order to draw firm conclusions, however, longitudinal studies are needed to determine long-term effect.

Conclusion

The findings suggested that learning through MyKimDG was more effective than the conventional method at supporting a higher achievement in the Salt chapter, 21st century skills and motivation in chemistry. In particular, it is proven that MyKimDG may improve students' high productivity skills and self-efficacy. However, MyKimDG can likely be improved to increase students' achievement in other domains of 21st century skills and motivation in chemistry. Notwithstanding, this study provide some evidence that the inclusion of student as game designer approach in chemistry learning is able to increase students' achievement and motivation in chemistry as well as their 21st century skills.

References

Amin, H. M., Jaafar, J., Hood, Z., Saad, S., & Amin, H. M. (2013). Kemahiran insaniah pelajar prasiswazah: Analisis perbezaan jantina. *Jurnal Teknologi (Social Sciences)*, *61*(1), 19–25.

Ariffin, T. F. T. (2005). Gender differences in computer attitudes and skills. *Jurnal Pendidikan*, *30*, 75–91.

Balaban, A. T., & Klein, D. J. (2006). Is chemistry "The Central Science"? How are different sciences related? Co-citations, reductionism, emergence, and posets. *Scientometrics*, *69*(3), 615–637.

Balci, C., & Yenice, N. (2016). Effects of the scientific argumentation based learning process on teaching the unit of cell division and inheritance to eighth grade students. *Journal of Education in Science, Environment and Health (JESEH)*, *2*(1), 67–84.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: Freeman.

Baytak, A., & Land, S. M. (2010). A case study of educational game design by kids and for kids. *Procedia - Social and Behavioral Sciences*, *2*, 5242–5246.

Brown, T. L., LeMay, H. E., Bursten, B. E., Murphy, C., & Woodward, P. (2011). *Chemistry: The central science* (12th ed.). New Jersey: Prentice Hall.

Bruner, J. S. (1962). *On knowing: Essays for the left hand*. Cambridge, MA: Harvard University Press.

Capar, G., & Tarim, K. (2015). Efficacy of the cooperative learning method on mathematics achievement and attitude: A meta-analysis research. *Educational Science: Theory & Practice*, *15*(2), 553–559.

Chang, R. (2007). *Chemistry* (9th ed.). New York, NY: McGraw-Hill.

Deci, E. L., Vallerand, R. J., Pelletier, L. G., & Ryan, R. M. (1991). Motivation and education: The self-determination perspective. *Educational Psychologist*, *26*(3&4), 325–346.

Demircioglu, T., & Ucar, S. (2015). Investigating the effect of argument-driven inquiry in laboratory instruction. *Educational Research and Evaluation*, *15*(1), 267–283.

Gilbert, J. K., & Treagust, D. F. (2009). Introduction: Macro, submicro and symbolic representations and the relationship between them: Key models in chemical education. In J. K. Gilbert & D. Treagust (Eds.), *Multiple representations in chemical education* (pp. 1–8). Dordrecht: Springer Netherlands.

Hew, T. S., & Leong, L. Y. (2011). An empirical analysis of Malaysian pre-university students' ICT competency gender differences. *International Journal of Network and Mobile Technologies*, *2*(1), 15–29.

Hwang, G.-J., Sung, H.-Y., Hung, C.-M., Yang, L.-H., & Huang, I. (2013). A knowledge engineering approach to developing educational computer games for improving students' differentiating knowledge. *British Journal of Educational Technology*, *44*(2), 183–196.

Iksan, Z., Halim, L., & Osman, K. (2006). Sikap terhadap sains dalam kalangan pelajar sains di peringkat menengah dan matrikulasi. *Pertanika Journal of Social Sciences & Humanities*, *14*(2), 131–147.

Jung, J. Y., & Park, H. (2009). Learning by doing via game making. In D. Gibson & Y. Baek (Eds.), *Digital simulations for improving education: Learning through artificial teaching environments* (pp. 394–406). Hershey, PA: Information Science Reference.

Kafai, Y. B. (1996). Learning design by making games: Children's development of design strategies in the creation of complex computational artifact. In Y. Kafai & M. Resnick (Eds.), *Constructionism in practice: Designing, thinking, and learning in a digital world* (pp. 71–96). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Kafai, Y. B., & Ching, C. C. (1996). Meaningful contexts for mathematical learning: The potential of game making activities. In *Proceedings of the 1996 International Conference on Learning Sciences* (pp. 164–171).

Lay, A.-N., & Osman, K. (2015). Framework for 21st century chemistry instruction: A guide to teaching and learning of Qualitative Analysis. *Technics Technologies Education Management*, *10*(2), 216–230.

Lee, T. T., & Osman, K. (2014). Development of Interactive Multimedia Module with Pedagogical Agent (IMMPA) in the learning of electrochemistry: Needs assessment. *Research Journal of Applied Sciences, Engineering and Technology*, *7*(18), 3725–3732.

Lim, C. P. (2008). Spirit of the game: Empowering students as designers in schools? *British Journal of Educational Technology*, *39*(6), 996–1003.

Ministry of Education Malaysia. (2013). *Pelan Pembangunan Pendidikan Malaysia 2013-2025*. Putrajaya: Kementerian Pendidikan Malaysia.

Morrison, G. R., Ross, S. M., Kalman, H. K., & Kemp, J. E. (2013). *Designing effective instruction* (7th ed.).

New York: John Wiley & Sons, Inc.
OECD. (2014). *PISA 2012 results: Creative problem solving: Students' skills in tackling real-life problems (Volume V)*. PISA, OECD Publishing.
OECD. (2016). *Measuring science, technology, and innovation*. Paris: OECD Publishing. Retrieved from https://www.oecd.org/sti/STI-Stats-Brochure.pdf
Osman, K., & Marimuthu, N. (2010). Setting new learning targets for the 21st century science education in Malaysia. *Procedia - Social and Behavioral Sciences*, *2*, 3737–3741.
Osman, K., & Bakar, N. A.. (2013). Teachers and students as game designers: Designing games for classroom integration. In S. de Freitas, M. Ott, M. M. Popescu, & I. Stanescu (Eds.), *New pedagogical approaches in game enhanced learning: Curriculum integration* (pp. 102–113). Hershey, PA: IGI Global.
Osman, K., Iksan, Z., & Halim, L. (2007). Sikap terhadap sains dan sikap saintifik di kalangan pelajar sains. *Jurnal Pendidikan*, *32*, 39–60.
Palmer, D. (2005). A motivational view of constructivist-informed teaching. *International Journal of Science Education*, *27*(15), 1853–1881.
Papert, S. (1991). Situating constructionism. In I. Harel & S. Papert (Eds.), *Constructionism* (pp. 1–28). Norwood, NJ: Ablex Publishing Corporation.
Papert, S. (1998). Does easy do it? Children, games, and learning. *Game Developer Magazine*, *Jun*, 88.
Papert, S. (1999). *Eight big ideas behind the constructionist learning lab* (Vol. 405). Retrieved from http://stager.org/articles/8bigideas.pdf
Piaget, J. (1977). *The development of thought: Equilibration of cognitive structures*. New York, NY: Viking Press.
Prensky, M. (2008). Students as designers and creators of educational computer games: Who else? *British Journal of Educational Technology*, *39*(6), 1004–1019.
Prensky, M. (2012). *From digital natives to digital wisdom: Hopeful essays for 21st century learning*. Thousand oaks, CA: Corwin.
Rieber, L., Barbour, M., Thomas, G., & Rauscher, D. (2008). Learning by designing homemade powerpoint games. In C. T. Miller (Ed.), *Games: Purpose and potential in education* (pp. 23–42). New York, NY: Springer.
Sim, W. S. L., & Arshad, M. Y. (2015). Inquiry practices in Malaysian secondary classroom and model of inquiry teaching based on verbal interaction. *Malaysian Journal of Learning and Instruction*, *12*, 151–175.
Soh, T. M. T., Osman, K. & Arsad, N. M. (2012). M-21CSI: A validated 21st century skills instrument for secondary science students. *Asian Social Science*, *8*(16), 38–44.
Sukor, N. S., Osman, K., & Abdullah, M.. (2010). Students' achievement of Malaysian 21st century skills in chemistry. *Procedia Social and Behavioral Sciences*, *9*, 1256–1260.
Tan, K. C. D., Goh, N. K., Chia, L. S., & Treagust, D. F. (2002). A cross-age study on the understanding of the reactions involved in basic inorganic chemistry Qualitative Analysis. *Journal of Science and Mathematics Education in S.E. Asia*, *25*(2), 1–14.
Tan, Y. P., & Arshad, M. Y. (2014). Teacher and student questions: A case study in Malaysian secondary school problem-based learning. *Asian Social Science*, *10*(4), 174–182.
Tuan, H.-L., Chin, C.-C., & Shieh, S.-H. (2005). The development of a questionnaire to measure students' motivation towards science learning. *International Journal of Science Education*, *27*(6), 639–654.
UNCTAD. (2017). Science, technology and innovation for development. Retrieved from http://unctad.org/en/Pages/DTL/STI_and_ICTs/STI4D.aspx
Van Eck, R. (2006). Digital game-based learning: It's not just the digital natives who are restless. *EDUCAUSE Review*, *41*(2), 16–18, 20, 22, 24, 26, 28, 30.
Vos, N., van der Meijden, H., & Denessen, E. (2011). Effects of constructing versus playing an educational game on student motivation and deep learning strategy use. *Computers & Education*, *56*, 127–137.
Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

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Comparison of Pre-Service Physics Teachers' Conceptual Understanding of Dynamics in Model-Based Scientific Inquiry and Scientific Inquiry Environments

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Abstract

The focus of this study was to evaluate the impact of model-based inquiry on pre-service physics teachers' conceptual understanding of dynamics. Theoretical framework of this research was based on models-of-data theory. True-experimental design using quantitative and qualitative research methods was carried out for this research. Participants of this study were 22 senior pre-service physics teachers. The instructional strategy in the experimental class was model-based inquiry (MBI) while it was inquiry in the control class. Data were collected by using Force Concept Inventory (FCI), video recordings, inquiry reports and the instructor's field notes. The results of Mann-Whitney U tests for two classes' pre-tests and post-tests indicated that there was not any significant difference between two classes' performances before and after the treatment. On the other hand, the results of Wilcoxon signed-rank test showed that the experimental class's post FCI scores were better than their pre FCI scores. The following conclusions can be drawn from the study: Putting modelling explicitly into the center of inquiry facilitates conceptual learning. Therefore, model building and formation in inquiry can be seen as a way not only to represent what learners have already known but also to generate new knowledge. Making associations with other phenomena under the framework of epistemic characters of knowledge and expanding on these associations with discussions in inquiry learning environment promote students' understanding. Finally, model quality may stimulate science learning; however, more research is needed to extend this conclusion.

Introduction

Since there was not consensus in the literature about the specific components of scientific inquiry, Minner, Levy, Century (2010) looked for similarities across existing definitions of inquiry by reviewing literature that had been written over the course of the past 30 years and concluded that scientific inquiry instruction could be characterized as having three aspects: (1) the presence of science content, (2) student engagement with science content, and (3) student responsibility for learning, student active thinking, or student motivation within at least one component of instruction—question, design, data, conclusion, or communication. However, scientific inquiry teaching and learning approaches pose challenges for students such as failures to focus on the scientific merit of questions generated and to systematically collect and analyze data (Krajcik et al., 1998). Moreover, Mumba, Banda and Chabalengula (2015) have been categorized challenges of inquiry according to students as difficulties in written expressions, ability to link ideas in chains of reasoning, difficulties working with numeric data, and difficulties in spoken expressions.

While standards are advocating inquiry as an instructional strategy, it is also seen as problematic by many science teachers and has not been widely accepted or enacted (Campbell, Zhang & Neilson, 2011). The problems that teachers identify when seeking to employ inquiry as an instructional strategy are as follows: lack of clarity with respect to what constitutes inquiry, lack of examples of how inquiry is facilitated as an instructional strategy in real classrooms, and lack of the explicit association of inquiry with science content (Windschitl, Thompson and Braaten, 2008a).

Models are representations of a system to make its central features explicit while model formation is the construction of a model of some phenomenon by integrating pieces of information about the structure, function/behavior, and causal mechanism of the phenomenon, mapping from analogous systems or through induction (Gobert & Buckley, 2000). Models are essential as both content products of science (Gilbert &

Osborne, 1980) and in the process of coming to understand the world scientifically (Boulter, 2000; Crawford & Cullin, 2003; Harrison & Treagust, 2000; Viennot, 2001). Consequently, involving learners in modeling practices can help them build subject matter expertise, epistemological understanding, and expertise in the practices of building and evaluating scientific knowledge (Ogan-Bekiroglu, 2007; Schwarz et al., 2009). An important meaning in the context of model-based learning is the idea that students must learn to be able to think with chains or networks of causal relationships that are larger than a single A causes B relation (Clement, 2000). Modelling can be embedded in inquiry to overcome some of the concerns about inquiry.

The scientific modeling involving construction, use, evaluation, and revision of models embedded in the inquiry process can be generally defined as the model-based inquiry (Schwarz et al. 2009). Thus, the focus of this study was to evaluate the effect of model-based inquiry on pre-service teachers' conceptual understanding. Since most science teachers have never directly experienced authentic scientific inquiry during their education in the sciences or within teacher education programs (Hahn & Gilmer, 2000) and professional development must not only teach inquiry knowledge, but it must also assess and address teachers' core teaching conceptions (Lotter, Harwood & Bonner, 2007), pre-service teachers were the target in this study.

Theoretical Framework

Models-of-data theory developed by Chinn and Brewer (2001) frames this research. Based on this theory, an experiment or other forms of research can be represented as a model that integrates theoretical explanations with the observations and with the details of the data gathering procedures. Authentic scientific inquiry refers to the research that scientists actually carry out; however, many current classroom inquiry tasks bear little resemblance to authentic scientific reasoning (Chinn & Malhotra, 2002). Models-of-data theory helps us understand the difference between authentic inquiry and simple classroom inquiry. According to Chinn and Malhotra (2002), while scientists aim to develop and refine theoretical models in response to evidence in authentic inquiry; students aim to uncover a simple surface-level regularity and to understand a provided theory. That is, scientists engage in inquiry other than controlled experiments, use existing models in their inquiries, engage in inquiry that leads to revised models, use models to construct explanations, use models to unify their understanding, and engage in argumentation (Passmore, Stewart, Cartier, 2009).

Windschitl and his colleagues (2008a) offer an alternative vision for investigative science—model-based inquiry (MBI)—to capture the features of authentic science because authentic forms of inquiry for school science can be grounded in the following five epistemic ideas: testability, conjecture, explanation, principled revision, and generativity. MBI is an instructional strategy whereby learners are engaged in inquiry in an effort to explore phenomena and construct and reconstruct models in light of the results of scientific investigations (Campbell, Oh & Neilson, 2012). Campbell et al. (2011) point out that MBI is valuable because it offers some clarity with respect to defining inquiry, provides an example of how inquiry can be facilitated as an instructional strategy in an authentic context, and reveals how inquiry and science content learning can be juxtaposed to show a more realistic model of the processes of science.

Model construction and revision is fostered by building, critiquing, changing, and expressing one's conceptions of phenomena and modeling can occur through inquiry (Khan, 2007). Therefore, engaging learners in modeling-centered inquiry enables them to revise their own conceptual models and to use those revised models in reasoning (Passmore, 2009) as well as helps them deepening their scientific knowledge (Schwarz et al., 2009).

Literature Review on the Role of Inquiry in Science Learning

Minner and her colleagues asserted that the term inquiry refers to at least three distinct categories of activities—what scientists do (e.g., conducting investigations using scientific methods), how students learn (e.g., actively inquiring through thinking and doing into a phenomenon or problem), and a pedagogical approach that teachers employ (e.g., designing or using curricula that allows for extended investigations). Inquiry instruction could make abstract concepts more concrete, and by providing a valuable context, could position students better to acquire, clarify, and apply an understanding of scientific concepts (van der Meij, van der Meij & Harmsen, 2015). Some studies looking into the effectiveness of inquiry as an instructional strategy (Apedoe, 2008; Brown & Campione, 1994; Hakkarainen, 2003; Wallace, Tsoi, Calkin & Darley, 2003) presented positive results for increasing students' understanding. For instance, the question that Hakkarainen (2003) addressed in his study was whether 28 Grade 5/6 students, collaborating within a computer-supported classroom, could engage in inquiry. Results of the study indicated that with teacher guidance, students were able to produce meaningful intuitive explanations about biological phenomena and to engage in constructive peer interaction that helped them go beyond their intuitive explanations and toward theoretical scientific explanations. Wallace, Tsoi, Calkin and Darley (2003) investigated how five non-major biology students learned from an inquiry experience. Findings indicated that students with constructivist learning beliefs tended to add more meaningful conceptual understandings during inquiry activities than students with positivist learning beliefs. In addition, Hofstein, Navon, Kipnis and Mamlok-Naaman (2005) focused on the ability of asking meaningful and scientifically sound questions of high-school chemistry students, who learned chemistry through inquiry. Students enrolled in a laboratory course that utilized inquiry instruction asked more frequent higher-level questions during a chemistry lab practical than did their counterparts enrolled in a traditional course.

The conceptual benefits of engaging in inquiry are well documented. Nevertheless, Furtak (2006) stated that while meta-analyses suggested a positive influence on student learning, more recent studies comparing scientific inquiry classrooms to more traditional classrooms did not find positive results. For instance, Germann (1989) conducted his research in four high-school biology classes to test the inquiry approach to learning science process skills and scientific problem solving curriculum. In the 11-month intervening time, the experimental group received the inquiry instruction while the comparison group received a more traditional approach. Analysis of covariance revealed that the inquiry instruction had no significant effect on the learning of science process skills or on cognitive development. Pine and his colleagues (2006) studied the degree to which students could do inquiries by using four hands-on performance assessments, which required one or three class periods. The students were from 41 classrooms in nine school districts. Their results presented little or no curricular effect and there was no difference on a multiple-choice test, which used items released from the Trends in International Mathematics and Science Study (TIMSS).

Moreover, in a case study, Maxwell, Lambeth and Cox (2015) examined the effects of inquiry instruction on the academic achievement of 42 fifth-grade science students. After six-week instruction, students in the inquiry group scored higher than students in the traditional group on the academic achievement posttest; however, the result was not statistically significant. Furthermore, Minner et al. (2010) compared the studies done between 1984 and 2002. In looking more specifically at the 101 studies of student science conceptual understanding, they found that there was no statistically significant association between amount of inquiry saturation and increased student science conceptual learning. Therefore, they concluded that the evidence of effects of inquiry instruction from the synthesis was not overwhelmingly positive.

Because of the fact that researchers identified difficulties in students' generating knowledge during inquiry (Edelson, Gordin, & Pea, 1999) and the challenges of inquiry for both teachers and students mentioned in the introduction section have directed researchers to spend efforts on creating effective support in inquiry learning environments. MBI was proposed as a result of these efforts to support learning. Some researchers have explored technology's potential as a model based inquiry to overcome barriers in implementing classroom inquiry (Kim, Hannafin & Bryan, 2007).

Literature Review on Model-Based Inquiry

Although researchers argue that situating modelling in inquiry frames is effective for learning science content and understanding scientific practices (Campbell et al., 2012), there are relatively small number of studies that have closely examined effects of MBI on learning. For instance, Löhner, van Joolingen, Savelsbergh & van Hout-Wolters (2005) studied 42 secondary school students' reasoning during modeling in an inquiry learning environment from three schools, who had chosen to participate in the experiment as part of their regular coursework. The experiment took three hours in total. Students worked on their task in small groups of two or three. They found that students spent most of their time during inquiry modeling on scientific reasoning activities, but not in a systematic temporal order. In Khan's (2007) study, a one-semester introductory chemistry course was offered to 33 first-year science and non-science majors. In-depth problem-solving sessions were designed to document student learning by capturing and elaborating on students' model-based inquiries in rich detail. Results of the study showed that students' mental models of molecular structures enriched. On the other hand, Campbell and his colleagues (2011) studied the effect of MBI as an instructional strategy in comparison to a traditional lecture and demo (TLD) instructional strategy on a variety of student outcomes. The class that would serve as the MBI and TLD classes were assigned randomly. The MBI class consisted of 28 students while that TLD class consisted of 26 students. The Repeated Measurement of Variances analyses revealed that no significant differences were found in student outcomes for any of the domains when comparing physics classrooms facilitated with differing instructional strategies. In their research, Campbell et al. (2012) explored the emergent discursive modes and their pedagogical functions found in model-based inquiry (MBI) science classrooms. A sample of four high school physics classrooms was video-recorded and analyzed. Their results indicated that exploring was one of the most frequently used discursive modes in the MBI classrooms. Sun and Looi (2013) designed a web-based science learning environment for model-based inquiry. The participants included 46 students from two secondary classes and studied some electricity concepts. Their analysis demonstrated that the system could have a positive effect on students' conceptual understanding. Additionally, in a research conducted by Barab et al. (2000), three-dimensional animations and modeling tools enabled students to find evidence and manipulate variables efficiently by visualizing scientific concepts dynamically and authentically.

Though a few studies indicate the contributions of enactment of models and modelling explicitly in inquiry on students' outcomes, research that investigates the effectiveness of model-based inquiry by constructing a control group where the instruction is inquiry is not a commonly used approach. This study adds to the current research by exploring whether model-based inquiry facilitates conceptual knowledge of science by comparing it with inquiry.

Purpose of This Study

Even if ample time is allotted to authentic reasoning tasks, there will be serious instructional challenges for fostering the development of complex strategies (Chinn & Malhotra, 2002). Since, much of what pre-service teachers learn about inquiry and about teaching also comes from their experiences as undergraduates, there have been calls to integrate more authentic inquiry experiences into not only undergraduate science courses but into teacher education courses as well (Windschitl, 2003). An important aspect of addressing these experiences is enabling pre-service teachers to experience learning and teaching science by using model-based inquiry in a productive learning community (Schwarz et al., 2009). Therefore, the research question explored in this current study is as follows: Are there measurable differences in pre-service teachers' conceptual learning of dynamics when comparing two physics classes instructed with model-based inquiry and inquiry? In order to make sure that the participants revised their models as an aspect of modelling process, the following research question was also set: Do pre-service physics teachers revise and change their initial models into final models? How?

Methodology

True-experimental design using quantitative and qualitative research methods was carried out for this study (Krathwohl, 1997). A pretest/posttest control group design was conducted to monitor the change in pre-service teachers' understanding of the concepts of dynamics over time and to measure the effect of implementation of modelling during inquiry on their conceptual learning. For the quantitative aspect of the study, the researchers compared participants' learning statistically. The purposes of the qualitative part were to validate the quantitative results, to examine participants' learning during instruction to provide justification for the quantitative research, and to evaluate their models.

Participants and Settings

The research was conducted in two classrooms, one was experimental and one was control. Participants of this study were 22 senior pre-service physics teachers, 13 of whom were females. Ages of the participants ranged from 22 to 24 years. The participants were distributed randomly to the experimental and control classes. The experimental class was randomly selected by drawing lots. The instructional strategy in the experimental class was model-based inquiry (MBI) while it was inquiry in the control class. There were six females and five males in the experimental class. Anonymity was preserved by using codes for the participants; therefore, MB1 through MB11 represented the pre-service teachers in the model-based inquiry class and I1 through I11 represented the pre-service teachers in the inquiry class.

The study took place in an elective course called Conceptual Physics in the physics teacher education program at a state university. The course aimed to develop participants' conceptual knowledge of dynamics and help them reformulate their views of effective science teaching. The pre-service physics teachers in both classes took the course for 2 hours per week and worked as groups when it was necessary. In the experimental class, MB1 worked with MB2, MB3 worked with MB4, MB5 worked with MB6, MB7 worked with MB8, and MB9 worked with MB10 and MB11. The students constructed their models and conducted experiments as groups;

however, they designed their initial models, wrote their inquiry reports, and made their presentations about daily life events or scientists' models individually.

Treatment and Instructional Context

Both the experimental and control classes studied the same dynamics concepts with the same instructor. Since the pre-service teachers in the program knew the traditional laboratory activities but were not familiar with inquiry (Arslan, Ogan-Bekiroglu, Suzuk & Gurel, 2014), the instruction in the first and second weeks of the semester focused on implementation of inquiry in the control class and implementation of model-based inquiry in the experimental class. The model-based inquiry class was requested to generate initial models, develop inquiry questions, propose hypotheses, do investigations and conduct experiments to test their models. They constructed three-dimensional models and revised their models. The inquiry class was also requested to develop inquiry questions, propose hypotheses, do investigations and conduct experiments to test hypotheses. However, they were not asked to generate initial models in the beginning of the inquiry. Models were not the center of the inquiry in the control class. Five epistemic characteristics of scientific knowledge stated in the theoretical framework were considered to make a difference in both classes. Therefore, in the inquiry class, hypotheses were tested and conclusions summarized patterns in the data. On the other hand, in the model-based inquiry class, models were tested and revised, hypotheses were evaluated based on the models, and models were used for explanations. Table 1 demonstrates the similarities and differences in two classes.

Table 1. Inquiry and model-based inquiry implementations in the control and experimental classes

Control Class - Inquiry	Experimental Class – Model-Based Inquiry
Worksheet for the activity was distributed. The students were started to work as groups. They determined the problem and developed inquiry questions.	Worksheet for the activity was distributed. The students were started to work as groups. They generated initial models suggested processes or structures potentially explanatory of the phenomenon. They developed inquiry questions in tandem with their models.
The students stated potential relationships between variables and proposed hypotheses. They conducted experiments and took measurements to test the hypotheses.	The students stated potential relationships between variables and used their models to propose hypotheses. They conducted experiments and took measurements to test the models.
The students collected data and recorded measurements. They started to write their inquiry reports.	The students used models to collect data and evaluated the hypothesis. They modified their models if it was necessary. They started to write their inquiry reports.
The students discussed and analyzed the data and drew conclusions in conjunction with patterns in the data.	The students used patterns in the data and models to explain the phenomenon. They discussed and revised their models by taking into account additional evidence or aspects of the phenomenon.
The students presented their experiments as groups and discussed how their experiments could be used to test different hypotheses. They argued about if their conclusions could be explanations for other phenomena. They handed their inquiry reports in.	The students presented their models as groups and discussed how their models could generate different hypotheses. They argued about if their models could apply to other phenomena. They handed their inquiry reports in.

The participants in both classes worked on two inquiry activities during the course period. Each activity lasted five weeks. The first activity was about a half pipe in a skate park. The question was as follows: The person sitting on the deck of the half pipe showing in the picture wants to send a ball to his friend sitting on the opposite deck by rolling it in the pipe instead of throwing the ball. If height, transition and flat bottom of the half-pipe can be changed, how can the person send the ball as fast as possible?

The second activity was based on the difference between Galileo's and Aristotle's ideas about falling objects. The participants were given a discussion in an unfinished dialogue among three people and asked to explain who was right and who was wrong by providing evidence. They were also asked to complete the unfinished dialogue. The dialogue given in appendix was taken from the book written by Galileo Galilei, which was translated by Crew and Salvio in 1914. The names in the dialogue were changed. The participants in both classes involved with thought experiments and conducted free fall experiments in air, non-air and viscous liquid mediums. They argued about whether the knowledge they generated could be used to explain other phenomena such as some sports activities including bungee jumping, zorbing and cliff diving. Group and class discussions were carried out in both classes whenever needed. Instructional context in two classes is given in Table 2 week by week.

Table 2. Instructional context in two classes

Weeks	Inquiry Class	Model-Based Inquiry Class
1-2	Inquiry was explained as a teaching strategy and some cases were given as examples.	Model-Based Inquiry (MBI) was explained as a teaching strategy and some cases were given as examples.
3	Force Concept Inventory (FCI) was applied as the pre-test.	FCI was applied as the pre-test.
4-8	Inquiry was implemented for the first activity. Experiments were related to an inclined plane.	MBI was implemented for the first activity. Experiments were related to an inclined plane.
9-13	Inquiry was implemented for the second activity. Experiments were related to free fall of various objects with different features in various mediums.	MBI was implemented for the second activity. Experiments were related to free fall of various objects with different features in various mediums.
14	FCI was applied as the post-test.	FCI was applied as the post-test.

Role of the Researchers

The authors of this paper were physics educators. The first author was the instructor of the course; therefore, she had two roles. One was as a teacher and the other one was as a researcher. Two researchers prepared the lesson plans and worksheets together both for the control class and for the experimental class to make sure that the only difference between the classes was modelling. The first author observed and guided the groups, started and led discussions, and prevented irrelevant talk during the activities. Her behaviors were the same during the administrations of the FCI in both classes. Both authors had roles in planning the activities, conducting the research, and analyzing the data.

Data Collection Methods

Data were collected from the control and experimental classes by using the same methods. The Force Concept Inventory (FCI) was administered in the pre- and post-tests during the third and fourteenth weeks of the course. The FCI was developed by Hestenes et al. (1992) and revised by Halloun et al. (1995), as cited in Mazur (1997). This inventory has been translated to many languages and used in much international research to measure learning of dynamics concepts (Savinainen & Scott 2002). The FCI measures the following six fundamental concepts in general: kinematics, Newton’s First Law, Newton’s Second Law, Newton’s Third Law, superposition principle, and kinds of force. Some of the questions measure more than one concept. There are 30 multiple-choice questions in the FCI.

In order to understand the students’ reasoning and to assess their conceptual learning in detail, the students were required to write their justifications for their choices of the questions during both applications of the inventory. The 11-week duration between the pre- and post-tests helped the researchers to control the effect of retesting (Krathwohl 1997). Internal consistency computed by the Kuder Richardson formula 20 was high (Salvucci, Walter, Conley, Fink, & Saba, 1997) with reliability coefficients of 0.75 for the pre-test and 0.79 for the post-test. Furthermore, the participants in both classes and the instructor were videotaped during the instruction.

The groups were also tape-recorded while they were working on the activities. The groups’ inquiry reports and the instructor’s field notes were also data sources. These multiple data sources were used to be make sure that the participants followed the inquiry and model-based inquiry processes, to assess their conceptual understanding, and to evaluate their models.

Data Analysis

A bidimensional coding scheme developed by Hogan and Fisherkeller (1996) was used to analyze the participants' responses in the pre- and post-tests. In order to do statistical analysis, scores from 0 to 6 were assigned to the codes. If a student chose the correct answer, her explanation was consistent with scientific knowledge and it was detailed or adequate, her response was coded as "compatible elaborate" and given "6". If a student chose the correct answer, her explanation was consistent with scientific knowledge but it was superficial or inadequate, her response was coded as "compatible sketchy" and given "5". If a student chose the correct choice but her explanation was not scientific, her response was coded as "compatible/incompatible" and given "4". On the other hand, if a student's choice was not correct, her explanation was inconsistent with scientific knowledge and it was shallow, her response was coded as "incompatible sketchy" and given "3". If a student's choice was not correct, her explanation was inconsistent with scientific knowledge and it was detailed with unrelated concepts, her response was coded as "incompatible elaborate" and given "2". If a student made a choice, whether it was correct or not, but she did not explain the reason, her response was coded as "no evidence" and given "1". If a student neither made a choice nor gave an explanation, her response was coded as "no response" and given "0".

Question 28 is provided as an example for each response code. The question is as follows: Student "a" has a mass of 95 kg and student "b" has a mass of 77 kg. They sit in identical office chairs facing each other. Student "a" places his bare feet on the knees of student "b". Student "a" then suddenly pushes outward with his feet, causing both chairs to move. During the push and while the students are still touching one another:

A. Neither student exerts a force on the other.
B. Student "a" exerts a force on student "b," but "b" does not exert any force on "a."
C. Each student exerts a force on the other, but "b" exerts the larger force.
D. Each student exerts a force on the other, but "a" exerts the larger force.
E. Each student exerts the same amount of force on the other.

Compatible elaboration: "The correct answer is "E" because mass does not have any effect here. Based on Newton's Third Law of motion, when student "a" exerts the force on student "b," student "b" exerts the equal and opposite force on student "a".
Compatible sketchy: "The correct answer is "E" because both students exert the same amount of force on each other".
Compatible/incompatible: "The correct answer is "E" because the same amount of force during the interaction makes the students stop".
Incompatible sketchy: "The correct answer is "D" because slim people lose rope-pulling contests.
Incompatible elaboration: "The correct answer is "D" because student "a" was heavier than student "b" and also because there was a pushing force, student "a" exerts the larger force".
No evidence: "The correct answer is "E". No reason is given.

The coding scheme of the students' knowledge before and after the instruction was made by the first author. To assess the reliability of this coding, the second author randomly selected 10 questions from the pre- and post-tests and coded the participants' knowledge. Then, the two authors compared their coding and were able to reach 92 % agreement. The reliability measured by Cohen's κ was 0.76. There seems to be general agreement that Cohen's κ value should be at least 0.60 or 0.70 (Wood 2007). Consequently, the coding done for the participants' knowledge had adequate reliability. The authors reviewed the knowledge levels that they could not have agreement on and the final coding scheme was constructed by reaching consensus. The first author then revised all the codes of the participants' conceptual knowledge one more time. Mann Whitney U tests were used to compare the experimental class's performances with the control class's performances. Wilcoxon signed-rank tests were performed in order to make comparisons within the classes.

Tape and video records were transcribed. Then, content analysis approach was used to analyze the instructor's field notes, transcripts and the participants' inquiry reports to identify any conceptual change in the participants' mental models and the justifications for that. The students' initial and final models were examined from three perspectives: the nature of models, the function of models, and the role of models in inquiry (Windschitl, Thompson & Braaten, 2008b). Their models were rated based on each of these perspectives and the criteria listed in Table 3. A rating of "3" represented models that were most congruent with those of experts, a rating of "1" represented models that were least congruent with those of experts, and "2" represented an intermediate level of sophistication for models. The participants constructed their initial and final models as groups.

Table 3. Criteria for model evaluation (Windschitl, Thompson & Braaten, 2008b).

Nature of Models	Function of Models	Role of Models in Inquiry
"3" Most congruent with experts' models		
Can portray conceptual/theoretical as well as observable processes and relationships.	Tools to advance scientific ideas rather than only being a product of inquiry are generalizable, can be used to predict.	Research questions are conceived of within the context of a model.
Represent ideas rather than "things."	Tools to advance scientific ideas rather than only being a product of inquiry allow novel insights into relationships, and help generate questions for inquiry.	Hypotheses are parts of models that will be tested.
Models fallible in concept because they are based on interpretation and inference.		Models are revised through argument that uses data and logic, must be consistent with evidence, other models, theories.
Models have logical limits and underlying assumptions.		Empirical data can be used to argue for theoretical "pieces" (structures or processes) of models.
Models can differ not only because of representational modes, but because a phenomenon is totally reconceptualized.		Models can change not only as result of empirical "fine-tuning" but also because target phenomenon is reconceptualized in new way.
"2" Intermediate		
Models portray processes and systems that may not be directly observable, but are taken to be real.	Facilitates understanding, helps others to understand what an expert knows.	Scientific inquiry is done first, then create a model based on data.
Models can take form of mathematical representation or set of rules.	Are generalizable, used to describe different situations.	Models can help one think of things to investigate.
Models of same thing can be different because there are different modes of representation.	Helps analyze effects/variables of some complicated system.	Hypotheses are models.
		Data can be collected from models themselves. It is important to collect data on actual phenomenon (rather than exclusively from a model) if possible. Models are changed only if they do not match/predict data.
"1" Least congruent with experts' models		
Models are pictorial or physical replications of "things" considered to be real.	To simplify, illustrate, show	Model development not recognized as part of scientific inquiry; models function only to illustrate, simplify, help communicate ideas.
Object of model may be too small, too large or inaccessible to direct observation.		Hypotheses are "best guesses" from unspecified background knowledge.
Relation of model to thing being modeled: object of model is more complex.		Relationships between empirical observations and theory unspecified.
Models can be different from one another because of different "looks" at the object.		Fact that data can be collected from models themselves is unacknowledged.
		Argument may be synonymous with "conclusions" directed toward determining if questions are answered rather than using patterns in data to support or refute models.

Results and Discussion

The results of Mann-Whitney U tests for two classes' pre-tests showing in Table 4 and post-tests showing in Table 4 indicate that there was not any significant difference between two classes' performances before and after the treatment. This finding is in line with the result of the research done by Campbell et al. (2011), who compared MBI with traditional instructional strategy. Table 5 illustrates that the difference between the control class's pre- and post-test performance based on Wilcoxon signed-rank test was not significant, either.

Table 4. The results of Mann-Whitney U test for the classes' pre-test and post-test scores

Groups	N	Mean Rank	Sum of Ranks	MWU	z	p
Inquiry Pre-Test	11	12.73	140.00	47.000	-.887	.401
MBI Pre-Test	11	10.27	113.00			
Inquiry Post-Test	11	12.27	135.00	52.000	-.558	.606
MBI Post-Test	11	10.73	118.00			

On the other hand, according to Table 5, the results of Wilcoxon signed-rank test for the experimental class were in the expected direction ($z = -2.667$) and sum of positive ranks was significantly higher than the sum of negative ranks ($p<.01$). That is, the experimental class's post FCI scores were better than their pre FCI scores (mean rank of 6.30 vs. mean rank of 3.00). These findings present that model-based inquiry supported the learning process. When the students were given a chance to generate and revise models, they tended to select the scientific choices of the questions from the FCI, made better explanations for their choices and reached higher level of conceptual understanding. This result is consistent with the results that emerged from the research by Khan (2007) and Sun and Looi (2013).

Table 5. The results of Wilcoxon signed-rank test for the control (inquiry) and experimental (MBI) classes

Cont. Post-Test – Cont. Pre-Test	N	Mean Rank	Sum of Ranks	z	p
Negative Ranks	4	3.75	15.00	-1.602	.109
Positive Ranks	7	7.29	51.00		
Ties	0				
Total	11				
Exp. Post-Test – Exp. Pre-Test	N	Mean Rank	Sum of Ranks	z	p
Negative Ranks	1	3.00	3.00	-2.667	.008
Positive Ranks	10	6.30	63.00		
Ties	0				
Total	11				

Table 6 enables to analyze participants individually by providing their mean scores of the fundamental six concepts measuring in both pre- and post- administrations of the FCI and their differences. Regarding Table 6, nine students in the model-based inquiry class and nine students in the inquiry class revealed overall conceptual progression from pre-test to post-test considering the sum of differences in mean scores of the fundamental concepts (see the last column). Overall improvement of seven students (MB1, MB2, MB5, MB6, MB7, MB9, and MB11) in the experimental class and overall improvement of five students (I, I2, I4, I10, and I11) in the control class were higher than the score of 3. On the other hand, there was a decay in conceptual knowledge of the following students: MB8, MB10, I6, and I8. Two activities did not directly cover all the subjects such as centripetal force in the questions. As a result, the students in both classes could not construct much new knowledge in every concept and did not establish remarkable significant differences between pre- and post-tests.

Table 7 shows mean values of ratings of the groups' initial and final models that they constructed in two activities based on three perspectives and also gives mean of these mean values. According to the table, the students in the model-based class revised and changed their models with regards to their nature and function as well as their roles in inquiry. Apart from Group 4, all the groups improved their models' roles in inquiry. Unfortunately, Group 4 whose members were MB7 and MB8 did not recognize model development as part of scientific inquiry. This finding illustrates that situating modelling in inquiry frames helped the participants understand building and testing of models was inquiry. It can be seen that all the groups increased their mean of mean values when they constructed final models. This finding is parallel with the finding that the students excepting for MB8 and MB10 in the model-based class increased their FCI scores (see Table 6). There might be a relation between students' model improvement and their conceptual development.

Table 6. The participants' mean scores of six fundamental concepts measured in the pre- and post- FCI administrations and their differences

P	Post MC1	Pre MC1	D1 = Post MC1 - Pre MC1	Post MC2	Pre MC2	D2 = Post MC2 - Pre MC2	Post MC3	Pre MC3	D3 = Post MC3 - Pre MC3	Post MC4	Pre MC4	D4 = Post MC4 - Pre MC4	Post MC5	Pre MC5	D5 = Post MC5 - Pre MC5	Post MC6	Pre MC6	D6 = Post MC6 - Pre MC6	D1 + D2 + D3 + D4 + D5 + D6
MB1	4.34	3.34	1	3.78	3.11	0.67	2.75	3	-0.25	3.75	1.25	2.5	5.17	3.33	1.84	5	3.8	1.2	6.95
MB2	5.5	5	0.5	5.89	5.89	0	5.5	5.25	0.25	4.75	2.5	2.25	5	5.33	-0.33	5	4.6	0.4	3.07
MB3	3.16	3.33	-0.17	3.44	2.55	0.89	3.75	4	-0.25	2.75	2	0.75	1.67	2	-0.34	2.8	3.13	-0.33	0.55
MB4	2.67	3.33	-0.67	3.33	3.44	-0.11	3	3	0	4	1.5	2.5	1.83	2.67	-0.83	2.93	3.2	-0.27	0.62
MB5	1.67	2.5	-0.83	3.11	2.11	1	3	1.5	1.5	5	2.5	2.5	2.5	1.5	1	3.2	2.93	0.27	5.43
MB6	3	2	1	2.33	2.67	-0.33	3.25	1	2.25	4	4.75	-0.75	2.33	2.33	0	4	2.47	1.53	3.7
MB7	4.67	3.67	1	2	2.44	-0.44	3.75	1.5	2.25	3	1	2	2.83	2.5	0.33	4.67	3.47	1.2	6.34
MB8	2.67	4.33	-1.67	1.89	2.11	-0.22	1	2.5	-1.5	4.5	2.5	2	2.17	1.83	0.33	3.33	3.33	0	-1.05
MB9	2.33	1.83	0.5	2.33	2.89	-0.55	2.25	1.75	0.5	5	3	2	3.33	2.5	0.83	3.47	3	0.47	3.74
MB10	2	1.83	0.17	2.11	1.78	0.33	1.75	1.5	0.25	2.25	4	-1.75	1.5	2	-0.5	2	2.8	-0.8	-2.3
MB11	3	1	2	3.55	2	1.55	4.5	1	3.5	3.25	1.5	1.75	3.17	2	1.17	2.53	2.6	-0.07	9.90
I1	3.67	3.17	0.5	4.22	3.55	0.67	3	3	0	4	3.75	0.25	4.5	3.17	1.33	4.6	2.2	2.4	5.15
I2	3.67	3.33	0.33	4.11	3.22	0.89	3.5	3.25	0.25	3	3	0	4.17	3.33	0.83	4.47	2.4	2.07	4.37
I3	4.33	3.33	1	3.22	3.78	-0.55	3.75	3.75	0	4.25	3.75	0.5	3	3.17	-0.17	4.13	3.27	0.87	1.64
I4	3.83	2.83	1	3.44	2.67	0.78	5	2.5	2.5	3	2	1	2.83	2.67	0.17	3.87	3.53	0.33	5.78
I5	3.33	2.83	0.5	3.78	3.23	0.55	3.25	2.5	0.75	6	6	0	4	3.5	0.5	2.8	4.27	-1.46	0.84
I6	2.5	4.17	-1.67	1.89	3.44	-1.55	3.25	3.5	-0.25	4.25	4.5	-0.25	1.83	3	-1.17	3.53	3.53	0	-4.89
I7	5.5	4.67	0.83	4.33	5.33	-1	5.5	4.75	0.75	4.75	4.25	0.5	3.83	5	-1.17	5.73	4.67	1.07	0.98
I8	1	1.83	-0.83	1.78	1.55	0.22	1	1.25	-0.25	2	2	0	1.83	1.83	0	1.6	1.67	-0.07	-0.93
I9	2.17	2.33	-0.17	2.22	2	0.22	3.5	2.25	1.25	3.25	2.75	0.5	1.67	2.33	-0.66	1.2	2	-0.8	0.34
I10	3.17	3	0.17	3.44	2	1.44	3.25	3	0.25	5	3.25	1.75	3.33	1.5	1.83	2.6	2.93	-0.33	5.11
I11	3	2.17	0.83	3.89	2.11	1.78	4.25	1.25	3	3.5	2.5	1	2.17	1.83	0.33	3.33	1.87	1.47	8.41

P: Participant. MB: The participant in the model-based inquiry class. I: The participant in the inquiry class. MC1: Mean scores for the first concept i.e. kinematics. MC2: Mean scores for the second concept. i.e. Newton's First Law. MC3: Mean scores for the third concept i.e. Newton's Second Law. MC4: Mean scores for the fourth concept i.e. Newton's Third Law. MC5: Mean scores for the fifth concept i.e. superposition principle. MC6: Mean scores for the sixth concept i.e. kinds of force. D: Differences between post-test mean scores and pre-test mean scores. Post: Post administration of the FCI. Pre: Pre administration of the FCI

Most of the participants in the experimental class showed great progression for the fourth concept i.e. Newton's Third Law. The reason for this finding might be that these students discussed Newton's models of motion. They demonstrated force diagrams on their models and came to a conclusion that action and reaction forces did not exert on the same object. Additionally, MB5's, MB6's, MB7's, and MB11's knowledge of Newton's Second Law (third concept) developed well from pre-test to post-test. The questions assessing the knowledge of Newton's Second Law in the FCI were associated with motion of an object under various forces. These students spent much time discussing the ball's trajectory while they were working on their models for the duration of the first activity, so that they wrote scientific explanations for their choices in the post FCI administration. These findings support Löhner et al. (2005)'s idea that in an inquiry-modeling task, learners can learn about the domain by doing experiments and by expressing their acquired ideas in a model.

Table 7. Mean values of ratings of the groups' initial and final models that they constructed in two activities based on three perspectives and mean of mean values

Groups and Members	Initial Models				Final Models			
	Nature	Function	Inquiry	Mean	Nature	Function	Inquiry	Mean
1 (MB1, MB2)	1.5	1.5	1.5	1.5	2	2	2.5	2.17
2 (MB3, MB4)	2	2	2	2	2.5	2.5	2.5	2.5
3 (MB5, MB6)	2	1.5	1.5	1.67	2	2	3	2.67
4 (MB7, MB8)	1	1	1	1	1.5	1.5	1	1.34
5 (MB9, MB10, MB11)	1.5	1.5	1.5	1.5	1.5	1.5	2	1.67

MB1, MB2, MB5, and MB6 enhanced not only their conceptual knowledge but also their models. For example, Figure 1 presents initial model of MB1 and MB2 for the second activity while Figure 2 illustrates their final model for the same activity. Revising their initial models might cause revising their mental models.

MB11 provided more correct answers with their scientific explanations for the questions related to the concepts of kinematics, Newton's First, Second, and Third Laws during the post-test. His answers to the FCI questions were more detailed and supported with visual diagrams during the post-test. He was very active during the discussions.

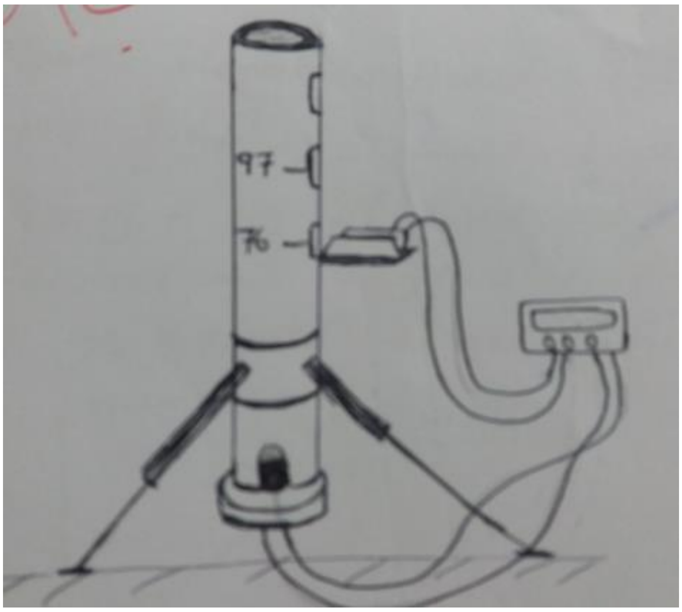

Figure 1. . Initial model of MB1 and MB2 for the second activity

He was the only one in the class who could generate mathematical model of acceleration. Besides, he could indicate in their initial model and explain how two objects having different masses drop on the floor at the same time in a frictionless medium.

Figure 2. Final model MB1 and MB2 for the second activity

MB3 and MB4 were in the same group and they showed little conceptual growth. The first model they created focused on the relationship between friction and heat. They tried to make a correlation between free fall and height in their second model. Since they did not analyze force diagrams in none of their models and could not take much measurement on their models, they might not improve their understanding. These findings seem to be in agreement with Löhner et al. (2005)'s expectation that the different representations used in modeling tools may have differential effects on students' reasoning processes. Likewise, Ogan-Bekiroglu (2007) concluded that the closer students' models were to the real situations, the more scientific conceptions they gained. The limitations of their models might not facilitate conceptual progress of MB3 and MB4. While MB3 and MB4 were presenting their second model, the following conversation occurred between them and the instructor:

Instructor: If action and reaction is equal to each other, why do we not fly? Or why does this glass stand on the table?
MB3: Because there is a gravitational force as an extra force.
MB4: To me it has an initial velocity.
Instructor: There is no movement. Can you explain to me what you are saying?
MB3: Our action force is not equal to our reaction force. Gravitational force is heavier.

Unfortunately, MB10 was not in the class most of the time. His mean scores of six concepts generally dropped or they increased very little from the pre-test to post-test of the FCI (see Table 6). He provided much explanation for his nonscientific choices during the pre-test. His choices were different but again nonscientific in the post-test. Moreover, this time he did not give detailed explanation for them. Moreover, the researcher realized that MB10 had some misconceptions during their informal conversation while the students were working on their models. An excerpt from the conversation is given below:

MB9: This is a reaction force. What would happen if this force does not exist? What would happen to the object if the reaction force does not exist?
MB10: The object would not exist.
MB11: One second! The object would not move; it would stand still.
MB10: It would be flying.
MB9: N = mg. There is a reaction force exerting on the object.
MB11: Yes, it's true.
.....
Instructor: Is the object standing still?
MB10: Yes.
MB1: The net force on the y axis is zero.
Instructor: Why?
MB1: Action and reaction forces are in balance.
Instructor: Do the action and reaction forces cancel each other?
MB9: Exactly
MB10: They are equal but they are in opposite directions.

MB7 and MB8 were in the same group and generated their models together. However, MB7 did most of the work while MB8 did not contribute much. MB8's involvement with modelling process might affect her conceptual development so that her overall scores fell by 1.05 points.

I1 and I2 demonstrated conceptually higher performance in the post-administration of the FCI for the concept of kinds of force (sixth concept) than in the pre-administration of the FCI. This result is compatible with the result presented by Hakkarainen (2003). I1 generally gave detailed explanations for her choices even her choices were scientific or not. Due to the fact that her choices were more scientific during the post-test, there appeared a big difference between her pre- and post-test scores. She was a teaching assistant in lab sections and could define dependent and independent variables correctly. She produced nine research questions for the first activity and five research questions for the second activity.

Both I1 and I2 participated in the class discussions enthusiastically. I1 related her second experiment with bungee jumping and explored the importance of tension of the rope as well as gravity. I2 could make fault analyses in their experiment and revised it. She expanded on Felix Baumgartner's jumping to Earth from a helium balloon in the stratosphere while examining free fall and gravity. These daily life connections and active participation might enable them to make improvement in their conceptual knowledge. The dialog given below passed between I1 and I2 during their first experiment:

I1: We considered coefficient of friction. It is important for us. Height of the point where the ball is held by the child is also important because the ball has a potential energy due to the fact that it does not have any initial velocity. If it has initial velocity, it is important too. We think that mass of the ball is negligible.
I2: Yes, mass of the ball is not taken into consideration.
Instructor: Why is that?
I2: When we construct an energy equation, the masses on the left and right cancel each other out.

I11 left his misconceptions and gained scientific knowledge for the concepts of Newton's First and Second Laws as well as kinds of force during the post-administration of the FCI. He searched for g-max experience and elucidated the physics laws working during this experience. Although he chose the scientific answer in the pre-test, he did not explain the reason behind his answer. He focused more on theory during the inquiry process and examined the system of a catapult by himself to perform his experiment. His research question was in line with his hypothesis unlike most of other students. Finally, he offered detailed statements for his scientific choices during the post administration of the FCI.

On the other hand, I6's scores decreased from pre-test to post-test for all the concepts apart from kinds of force. She always passed the deadline for handing inquiry reports in and could not attend most of the classes. She made connections with her past experiences but did not consider theoretical propositions and formulas during the inquiry activities. She could try to explain cliff diving but her explanations were weak in terms of including scientific schemes. These situations might cause regress in her reasoning.

Examination of Table 6 also allows us to compare experimental and control classes' performances based on the fundamental concepts assessed in the FCI. The number of students who gained scientific knowledge was equal in both classes for the concepts of Newton's Second Law, superposition, and kinds of forces. Regarding the concepts of kinematics and Newton's First Law, more number of participants in the inquiry class improved their understanding then the number of participants in the model-based inquiry class. The participants in the inquiry class extended their conclusions to the sportsmen's movement, their trajectory and the forces exert on them. These examples might cause shift in some of the students' misconceptions so that their answers in the post-test became more scientific. The students in the inquiry class also elicited buoyancy and drew force diagrams during the sports activities including jumping. In addition, I11 presented mathematical models allied with a catapult and rotational motion. These generations might cause the cognitive improvement for the students in the inquiry class for the concepts of kinematics and Newton's First Law.

The model-based inquiry class discussed Galilei's model and discovered how he reached the concept of acceleration by changing the angle of inclination. Moreover, they compared Aristotle's question "what causes an object to move" to Descartes's question "what causes an object to stop moving". These discussions might help some students' progress conceptually. On the other hand, more number of students in the model-based inquiry class gained knowledge of Newton's Third Law than the number of students in the inquiry class. This concept was argued in both activities in the experimental class. There might be a chance that the more time students involve in modelling process the more their mental models improve.

Conclusions

Keselman (2003) states that inquiry learning cannot be achieved merely by placing students in the midst of a complex scientific domain for free-reign investigation. Since simple inquiry tasks may fail to help students learn to reason scientifically (Chinn & Malhotra, 2002), it has been argued in this research that the process of revising models that learners themselves constructed through inquiry activities to reflect advances in their understanding was more effective than traditional inquiry activities. This argumentation is based on Passmore et al. (2009)'s hypothesis about model-based learning. The following conclusions can be drawn from the study: Putting modelling explicitly into the center of inquiry facilitates conceptual learning. Therefore, model building and formation in inquiry can be seen as a way not only to represent what learners have already known but also to generate new knowledge. Keselman (2003) also claims that it is important that teachers conclude classroom inquiry learning activities with discussion and clarification sessions, ensuring that students do not walk away from these activities with incorrect conceptual information. To reconceptualize school science inquiry, researchers (Smith, Maclin, Houghton, & Hennessey, 2000; Windschitl, Thompson, & Braaten, 2007) advocate for coordinating the language and activities in classrooms around five epistemic features of scientific knowledge. Consequently, making associations with other phenomena under the framework of epistemic characters of knowledge and expanding on these associations with discussions in inquiry learning environment promote students' understanding. In addition, if students involve in model-based inquiry activities in an adequate duration, their conceptual knowledge of science would reinforce. Finally, model quality may stimulate science learning; however, more research is needed to extend this conclusion because it comes from the group results.

Implications and Further Study

In this research, the students engaged in authentic inquiry like scientists do with the help of model-based inquiry. The current study contributes to the science education literature toward a better understanding of model-based inquiry as an instructional strategy in an authentic context. Model-based inquiry would be embedded in science teacher education programs to improve teacher candidates' science content knowledge and inquiry skills. For teachers and instructors, activities in this study would be examples of how inquiry and model-based inquiry can be implemented in science classrooms.

Further research would make comparison between learning and model quality in an individual basis. Moreover, studies would focus on how model-based inquiry capture the features of authentic science by examining participants' science process skills. Examination of participants' model understanding in a model-based inquiry environment would also make contribution in the area.

References

Apedoe, X. S. (2008). Engaging students in inquiry: Tales from an undergraduate geology laboratory-based course. *Science Education*, *92*, 631-663.

Arslan, A., Ogan-Bekiroglu, F., Suzuk, E. & Gurel, C. (2014). Examination of Physics Laboratory Classes According to Inquiry Activities and Determination of Pre-Service Teachers' Views. *Journal of Turkish Science Education*, *11*(2), 3-37.

Barab, S. A., Hay, K. E., Squire, K., Barnett, M., Schmidt, R., Karrigan, K., Johnson, C. (2000). Virtual solar system project: Learning through a technology-rich, inquiry-based, participatory learning environment. *Journal of Science Education and Technology*, *9*(1), 7-25.

Boulter, C. J. (2000). Language, models and modelling in the primary science classroom. In J. K. Gilbert & C. J. Boulter (Eds.), *Developing models in science education* (pp. 289-305). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Brown, A. L., & Campione, J. C. (1994). Guided discovery in a community of learners. In K. McGilly (Ed.), *Classroom lessons: Integrating cognitive theory and classroom practice* (pp. 229-270). Cambridge, MA: MIT Press/Bradford

Campbell, T., Zhang, D., & Neilson, D. (2011). Model based inquiry in the high school physics classroom: An exploratory study of implementation and outcomes. *Journal of Science Education and Technology, 20,* 258-269.

Campbell, T., Oh, P. S., & Neilson, D. (2012). Discursive modes and their pedagogical functions in model-based inquiry (MBI) classrooms. *International Journal of Science Education, 34*(5), 2393-2419.

Chinn, C. A., & Brewer, W. F. (2001). Models of data: A theory of how people evaluate data. *Cognition and Instruction*, *19*(3), 323-393

Chinn, C. A., & Malhotra, B. A. (2002). Epistemologically authentic inquiry in schools: A theoretical framework for evaluating inquiry tasks. *Science Education*, *86*, 175–218

Clement, J. (2000). Model based learning as a key research area for science education. *International Journal of Science Education*, *22*(9), 1041-1053.

Crawford, B. A., & Cullin, M. J. (2003, August). Dynamic assessment of prospective teachers' knowledge of models and modelling. Proceedings from ESERA' 2003: *Fourth Conference of the European Science Education Research Association*, Noordwijkerhout, The Netherlands.

Edelson, D. C., Gordin, D. N., & Pea, R. D. (1999). Addressing the challenges of inquiry-based learning through technology and curriculum design. *Journal of the Learning Sciences*, *8*(3-4), 391-450.

Furtak, E. M. (2006). The problem with answers: An exploration of guided scientific inquiry teaching. *Science Education*, *90*, 453-467.

Galilei, G. (2014). *Dialogues Concerning Two New Sciences by Galileo Galilei*. (H. Crew & A. Salvio, Trans.). New York, NY: Macmillan. (Original work published 1914).

Germann, P. J., (1989). Directed inquiry approach to learning science process skills: Treatment effects and aptitude treatment interactions. *Journal of Research in Science Teaching*, *26*(3), 237-250.

Gilbert, J. K., & Osborne, R. J. (1980). The use of models in science and science teaching. *European Journal of Science Education*, *2*(1), 3-13.

Gobert, I., & Buckley, B. (2000). Introduction to model-based teaching and learning in Science education. *International Journal of Science Education*, *22*(9), 891-894.

Hahn, L. L., & Gilmer, P. J. (2000, Oct.). Transforming pre-service teacher education programs with science research experiences for prospective science teachers. Paper presented at the annual meeting of the *Southeastern Association for the Education of Teachers in Science*, Auburn, AL.

Hakkarainen, K. (2003). Progressive Inquiry in a Computer-Supported Biology Class. *Journal of Research in Science Teaching*, *40*(10), 1072-1088.

Halloun, I., Hake, R., Mosca, E., & Hestenes, D. (1995). Force concept inventory. Available from http://modeling.la.asu.edu/modeling.html. Accessed 24 May 2001 (password protected)

Harrison, A. G., & Treagust, D. F. (2000). A typology of school science models. *International Journal of Science Education*, *22*(9), 1011-1026.

Hestenes, D., Wells, M., & Swackhamer, G. (1992). Force concept inventory. *The Physics Teacher*, *30*(3), 141-151.

Hofstein, A., Navon, O., Kipnis, M., & Mamlok-Naaman, R. (2005). Developing students' ability to ask more and better questions resulting from inquiry-type chemistry laboratories. *Journal of Research in Science Teaching*, *42*(7), 791-806.

Hogan, K., & Fisherkeller, J. (1996). Representing students' thinking about nutrient cycling in ecosystems: Bidimensional coding of a complex topic. *Journal of Research in Science Teaching*, *33*(9), 941–970.

Keselman (2003). Supporting inquiry learning by promoting normative understanding of multivariable causality. *Journal of Research in Science Teaching*, *40*(9), 898-921.

Khan, S. (2007). Model-Based Inquiries in Chemistry. *Science Education*, 91, 877-905.

Kim, M. C., Hannafin, M. J., & Bryan, L. A. (2007). Technology-enhanced inquiry tools in science education: An emerging pedagogical framework for classroom practice. *Science Education*, *91*, 1010-1030.

Krajcik, J., Blumenfeld, P. C., Marx, R. W., Bass, K. M., Fredricks, J., & Soloway, E. (1998). Inquiry in project-based science classrooms: Initial attempts by middle school students. *Journal of the Learning Sciences*, *7*, 313-350.

Krathwohl, D. R. (1997). *Methods of educational and social science research: An integrated approach*. Reading, UK: Addison-Wesley.

Lotter, C., Harwood, W. S., & Bonner, J. J. (2007). The influence of core teaching conceptions on teachers' use of inquiry teaching practices. *Journal of Research in Science Teaching*, *44*(9), 1318-1347.

Löhner, S., van Joolingen, W. R., Savelsbergh, E. R., & van Hout-Wolters, B. (2005). Students' reasoning during modeling in an inquiry learning environment. *Computers in Human Behavior*, *21*, 441–461.

Maxwell, D. O., Lambeth, D. T., & Cox, J. T. (2015). Effects of using inquiry-based learning on science achievement for fifth-grade students. *Asia-Pacific Forum on Science Learning and Teaching*, *16*(1), 1, Article 2.

Mazur, E. (1997). *Peer instruction: a user's manual*. Englewood Cliffs, NJ: Prentice-Hall.

Minner, D. D., Levy, A. J., & Century, J. (2010). Inquiry-based science instruction-What is it and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of Research in Science Teaching*, *47*(4), 474-496.

Mumba, F., Banda, A., & Chabalengula, V. M. (2015). Chemistry teachers' perceived benefits and challenges of inquiry-based instruction in inclusive chemistry classrooms. *Science Education International*, *26*(2), 180-194.

Ogan-Bekiroglu, F. (2007). Effects of model-based teaching on pre-service physics teachers' conceptions of the Moon, Moon phases and other lunar phenomena. *International Journal of Science Education*, *29*(5), 555-593.

Passmore, C., J. Stewart, and J. Cartier. 2009. Model-based inquiry and school science: Creating connections. *School Science and Mathematics*, *109*(7), 394-402.

Pine, j., Aschbacher, P., Roth, E., Jones, M., McPhee, C., Martin, C., Phelps, P., Kyle, T. (2006). Fifth graders' science inquiry abilities: A comparative study of students in hands-on and textbook curricula. *Journal of Research in Science Teaching*, *43*(5), 467-484.

Salvucci, S., Walter, E., Conley, V., Fink, S., & Saba, M. (1997). *Measurement error studies at the National Center for Education Statistics (NCES)*. Washington D. C.: U. S. Department of Education.

Savinainen, A., & Scott, P. (2002). The force concept inventory: a tool for monitoring student learning. *Physics Education*, *37*(1), 45–52.

Schwarz, C., Reiser, B., Davis, E., Kenyon, L., Acher, A., Fortus, D., Schwatz, Y., Hug, B., & Krajcik, J. (2009). Developing a learning progression for scientific modeling: Making scientific modeling accessible and meaningful for learners. *Journal of Research in Science Teaching*, *46*(6), 632-654.

Sun, D., & Looi, C. K. (2013). Designing a web-based science learning environment for model-based collaborative inquiry. *Journal of Science Education and Technology*, *22*, 73-89.

van der Meij, H., van der Meij, J., & Harmsen, R. (2015). Animated pedagogical agents effects on enhancing student motivation and learning in a science inquiry learning environment. *Educational Technology Research and Development*, *63*(3), 381-403.

Viennot, L. (2001). *Reasoning in physics: The part of common sense*. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Wallace, C. S., Tsoi, M. Y., Calkin, J., & Darley, M. (2003). Learning from inquiry-based laboratories in non-major biology: An interpretive study of the relationships among inquiry experience, epistemologies, and conceptual growth. *Journal of Research in Science Teaching*, *40*(10), 986-1024.

Windschitl, M. (2003). Inquiry projects in science teacher education: What can investigative experiences reveal about teacher thinking and eventual classroom practice? *Science Education*, *87*, 112-143.

Windschitl, M., Thompson, J., & Braaten, M. (2008a). Beyond the scientific method: Model-based inquiry as a new paradigm of preference for school science investigations. *Science Education*, *92*, 941-967.

Windschitl, M., Thompson, J., & Braaten, M. (2008b). How novice science teachers appropriate epistemic discourses around model-based inquiry for use in classrooms. *Cognition and Instruction*, *26*(3), 310-378

Wood, J. M. (2007). Understanding and computing Cohen's Kappa: A tutorial. WebPsychEmpiricist. Available from http://wpe.info/papers_table.html. Accessed 3 October 2007

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APPENDIX

Dialogue used in the Second Activity

Jack: The argument is, as you see, ad hominem, that is, it is directed against those who thought the vacuum a prerequisite for motion. Now if I admit the argument to be conclusive and concede also that motion cannot take place in a vacuum, the assumption of a vacuum considered absolutely and not with reference to motion, is not thereby invalidated. But to tell you what the ancients might possibly have replied and in order to better understand just how conclusive Aristotle's demonstration is, we may, in my opinion, deny both of his assumptions. And as to the first, I greatly doubt that Aristotle ever tested by experiment whether it be true that two stones, one weighing ten times as much as the other, if allowed to fall, at the same instant, from a height of, say, 100 cubits, would so differ in speed that when the heavier had reached the ground, the other would not have fallen more than 10 cubits.

William: His language would seem to indicate that he had tried the experiment, because he says: We see the heavier; now the word shows that he had made the experiment.

George: But I, William, who have made the test can assure you that a cannon ball weighing one or two hundred pounds, or even more, will not reach the ground by as much as a span ahead of a musket ball weighing only half a pound, provided both are dropped from a height of 200 cubits.

Jack: But, even without further experiment, it is possible to prove clearly, by means of a short and conclusive argument, that a heavier body does not move more rapidly than a lighter one provided both bodies are of the same material and in short such as those mentioned by Aristotle. But tell me, William, whether you admit that each falling body acquires a definite speed fixed by nature, a velocity which cannot be increased or diminished except by the use of force or resistance.

William: There can be no doubt but that one and the same body moving in a single medium has a fixed velocity which is determined by nature and which cannot be increased except by the addition of momentum or diminished except by some resistance which retards it.

Jack: If then we take two bodies whose natural speeds are different, it is clear that on uniting the two, the more rapid one will be partly retarded by the slower, and the slower will be somewhat hastened by the swifter. Do you not agree with me in this opinion?

William: You are unquestionably right.

Jack: But if this is true, and if a large stone moves with a speed of, say, eight while a smaller moves with a speed of four, then when they are united, the system will move with a speed less than eight; but the two stones when tied together make a stone larger than that which before moved with a speed of eight. Hence the heavier body moves with less speed than the lighter; an effect which is contrary to your supposition. Thus you see how, from your assumption that the heavier body moves more rapidly than the lighter one, I infer that the heavier body moves more slowly.

William: I am all at sea because it appears to me that the smaller stone when added to the larger increases its weight and by adding weight I do not see how it can fail to increase its speed or, at least, not to diminish it.

Jack: Here again you are in error, William, because it is not true that the smaller stone adds weight to the larger.

William: This is, indeed, quite beyond my comprehension.

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Using Inquiry-Based Strategies for Enhancing Students' STEM Education Learning

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Abstract

The major purpose of this study was to investigate whether or not the inquiry-based method is effective in improving students' learning in STEM (Science, Technology, Engineering, and Mathematics) education. Both quantitative and qualitative methods were used. A total of 73 college students studying Information Technology (IT) were chosen as participants. The instructional strategy used in this study was inquiry-based instruction. Participants were asked to answer a course satisfaction survey which utilized a 5-point Likert-type scale (a grade of 1 for least satisfied and 5 for highly satisfied); data obtained underwent means analysis. In addition, qualitative data including students' learning feedback and instructors' teaching feedback were collected and analyzed. The findings of this study includes: (1) students were highly satisfied on the STEM education learning program used in this study; (2) students' learning feedback also showed that they approved inquiry-based learning; and (3) instructors' teaching feedback showed that they preferred inquiry-based instruction as a teaching method. It can be concluded that the use of inquiry-based instruction can improve college students' STEM education learning.

Introduction

In recent years, limited higher education resources have made it difficult for Taiwan to keep up with the advancement of the global economy; this in turn, widened the knowledge-action gap in college education and caused disequilibrium in the supply and demand of undergraduates. Relative issues have been explored by many researchers (Chang & Kuo, 2008; Chang & Li, 2014; Chang & Tseng, 2014; Chang & Yuan, 2014; Chen & Lin, 2012; Kuo, 2014; Lai & Sheu, 2016; Lai, Tsai, & Yeh, 2015; Niu, 2014; Wu, 2014). Chen (2014) emphasized that rapid social changes, industrial transformation, and rapid expansion in higher education had created a knowledge-action gap and supply-demand disequilibrium in Taiwan's talents cultivation. This problem needs to be solved immediately.

Taiwan's Ministry of Education strongly advocates the streaming of the curriculum; a system which stresses that a university or college should offer not only academic disciplines but also practical ones. This course system aims to achieve knowledge-action integration in college education (Lai & Sheu, 2016) by closing the knowledge-action gap between academic training and industrial requirements for undergraduates, and reducing retraining that college graduates have to take when they enter the job market. Kuo (2014) pointed out that colleges and universities should strengthen students' international competitiveness and sustainably produce senior talents who can apply what they have learned.

In order to implement the knowledge-action integration initiative in higher education and to improve students' professional knowledge and skills, this study used industry-academy collaboration, which is an inquiry-based teaching model, to explore college students' academic performances in STEM courses.

Literature Review

The Development of Higher Education

Zhu (2013) pointed out that, in the era of globalization, the change of vacancies in job markets is accelerated by innovation, rapidly changing industry structure, and the increasingly frequent and complicated mobility of talents. For this reason, colleges and universities must innovate or reform teaching contents and methods in order to enhance students' competitiveness in job markets. He further emphasized that colleges and universities should enhance students' practice-oriented skills to meet enterprises' demands for innovative and professional talents. This may help college students smoothly start their careers upon graduation, reduce the ever-widening knowledge-action gap, and lessen the disconnection between education and industrial demands.

In 2012, the Council for Economic Planning and Development of Taiwan (2012) proposed a special scheme: *Plan for Reducing the Gap between Learning, Training, Examination and Employment* to fill the knowledge-action gap. In addition, Chen (2014) stated that observing overseas educational policies and practices may be helpful in solving this problem. For example, the European Union's human resources development established a program that mainly aims to: (1) urge the European people to have continuing education and to promote the quality of lifelong education; (2) promote the quality of career training and strengthen the multinational cooperation in career training; (3) help European youth develop professional knowledge and skills that the new era needs; (4) integrate academic research and social needs; (5) promote the collaboration between higher education institutes and enterprises.

Several researchers have proposed that colleges and universities should increase industry-academy collaboration, offer practice-oriented courses, and improve teachers' practical ability by enhancing their communication to effectively mend the knowledge-action gap (Chang & Li, 2014; Chen, 2014; Lai & Sheu, 2016; Lai, Tsai, & Yeh, 2015; Lee, 2013; Vinson, Reardon, & Rertoch, 2014; Wang, Huang, & Hsu, 2017; Yang, 2013). Yang (2013) suggested that to assist students' to find a job upon graduation, the design of practice-oriented courses should be based on industrial demands and social expectation, and the content of courses should help students develop their professional quality and innovation capability. In this way, colleges may closely combine schooling and employment and obtain greater educational and economic benefits.

Zhu (2013) held that when offering practice-based courses, an educational institution must first determine what competencies these courses can develop to help students in their chosen career after graduation. After that, various practice models including workplace experience, technical training, research participation and development, or establishment of a business should be used to promote the teaching.

Yu (2013) pointed out that practice-based courses could be taught and researched in the following two ways: (1) actively encourage teachers to observe and intern in enterprises to allow better understanding of their latest equipment, technology, industrial profile, and demands for talents, and closely integrate them to theories and practices; (2) invite industry experts to participate in team teaching. This may help enhance students' understanding of current industry trends which may aid in deciding their future career direction, and promote the benefits of industry-academy integration.

Chiu, Hsu, and Teng (2015) further stressed that higher education institutions should establish an industry-academy alliance with enterprises to provide an environment for practice-oriented courses learning and an opportunity to increase students' project experience and professional practice. Practice-based learning can help cultivate students' various abilities such as problem solving, communication, innovation, and interdisciplinary learning, which can transform learned information to professional knowledge.

In recent years, a growing number of researches have been conducted on the promotion of practice-oriented courses. The results showed that practice-oriented courses could improve college students' professional knowledge and skills (C. C. Chang, 2013; C. F. Chang, 2013; Chiu, Hsu, & Teng, 2015; Lo & Lee, 2014; Wang, 2013; Yu, 2013). Wang (2013) explained that long-term cooperation between academic departments and industry alliance could expand the added value of industry and academy, create new driving force for industry development, and foster an industry-oriented learning environment. This will help students gain industry information, develop technical skills, and improve employment competencies.

In summary, the problems brought by the knowledge-action gap and the supply-demand disequilibrium in the development of higher education in Taiwan require an immediate solution. The above literature review shows that increasing industry-academy collaboration and offering practice-oriented courses, two effective strategies to bridge the knowledge-action gap, are worth further exploration.

STEM (Science, Technology, Engineering, and Mathematics) Education

Human resource in science and technology is a fundamental aspect to a country's economic development; college students as future professionals in the field of science and technology are its important source. In recent years, due to the rapid change in the field of science and technology and the rise of interdisciplinary integration, STEM (Science, Technology, Engineering, and Mathematics) education has been in the limelight. Fan & Yu (2016) pointed out that STEM education was not only an issue that has aroused the attention of American educational circles, but also the focus of curriculum reform in many countries. This is because a number of advanced countries like the United States, have fully realized that students' academic performances in science, technology, engineering and mathematics determines a country's economic development and competitiveness.

STEM education is an integrated education that combines scientific inquiry, technology, engineering design, and mathematical analysis into a cohesive learning paradigm, including curriculum content, teaching activities, and educational policy. It aims to cultivate a country's future STEM talents and enhance its competitiveness. In addition, interdisciplinary courses may help increase students' interest in science, technology, engineering, and mathematics and keep students in line with modern science and technology (Chang & Yang, 2014; Duran, Höft, Lawson, Medjahed, & Orady, 2014; Fan & Yu, 2016; Liu, Wu, Hsieh, & Shen, 2013; Lou, Tsai, & Tseng, 2011; Oyana, Garcia, Haegele, Hawthorne, & Morgan, 2015; Reeve, 2015).

Chang and Yang (2014) pointed out that STEM was highly valued in American science education because it is an interdisciplinary approach that integrates science, technology, engineering and mathematics. The curriculum design can be linked to the development of modern science. Classroom discussions and hands-on training in this curriculum allow students to understand conceptual and procedural knowledge, and promote teamwork skills and creativity. Fan and Yu (2016) explained that STEM education emphasizes the cultivation of new abilities in the 21^{st} century, aimed at developing knowledge, attitudes, skills and abilities needed for Taiwan solving real-world problems and for adapting into the ever-changing modern society. Fan and Yu (2016) also summarized five targets of STEM education in the United States: (1) construct integrated STEM literacy; (2) improve American competitiveness in the 21^{st} century; (3) prepare America's STEM labor force (career exploration); (4) foster learning interest and stimulate participation willingness; and (5) develop the ability to connect STEM interdisciplinary knowledge.

Chang and Yang (2014) further noted that the former American president, Barrack Obama, had launched a plan to create the *STEM Master Teaching Corps* which aimed to applaud and award excellent STEM educators in America and improve the teaching of STEM practice. The plan was designed to improve students' performances in science and mathematics, develop their critical thinking, and promote their career competitiveness. In 2014, Obama expanded the plan and put forward a strategy to cultivate STEM talents across the United States.

Fan and Yu (2016) stated that STEM education focuses on guiding students to develop their ability to integrate interdisciplinary knowledge, stimulating their interest in STEM learning, and in helping them develop skills for future employment in STEM jobs as well as STEM literacy a global citizen should have in the 21^{st} century. They further pointed out that STEM programs often have the following essential attributes: (1) using real-world issues or problem situations; (2) designing a project-based, problem-oriented, or inquiry-based learning curriculum; (3) having explicit course objectives, content domains and learning indicators; (4) providing student-centered learning experiences; (5) stressing the connection and integration of STEM knowledge; (6) valuing the cultivation of high-level thinking such as logical thinking, problem solving, and critical thinking; and (7) emphasizing the connection between curriculum and job markets.

In terms of the implementation of STEM as a teaching method, Bybee (2010) suggested that challenging tasks or questions can be utilized to stimulate students to use STEM to find solutions. In addition, the knowledge students acquired in the process of problem inquiry and the abilities they developed in the process of seeking solutions can be measured by common core standards or other national competence standards (i.e. the Technology and Engineering Literacy Assessment developed by the National Assessment of Educational Progress (NAEP)).

With regards to the promotion of STEM teaching activities, scholars suggested that inquiry-based teaching strategy should be used to promote technology exploration, to practice teaching at a higher level, and strengthen the effect of STEM teaching (Barry, 2014; Chang & Yang, 2014; Cheng, Yang, Chang, & Kuo, 2016; Lai & Sheu, 2016).

Chang and Yang (2014) and Barry (2014) unanimously recommended adopting the 6E instructional model to improve the effect of STEM teaching. The model is an inquiry-based teaching strategy whose major teaching procedures include: (1) engaging, (2) exploring, (3) explaining, (4) engineering (elaborating), (5) enriching, and (6) evaluating.

To sum up, the purpose of STEM education lies in helping students improve their learning motivation for STEM courses and enhance STEM literacy, and in understanding how STEM knowledge can be utilized to solve real-life problems. Since human resources in science and technology is the basis of a nation's economic development, students should be encouraged to explore STEM fields and be supported to improve their academic performance in science, technology, engineering, and mathematics to promote economic growth and competitiveness of Taiwan.

Methods

This study utilized both quantitative and qualitative methods. A total of 73 undergraduates majoring in Information Technology (IT) in an academic institution were chosen as participants. Based on the literature review, the curriculum design and arrangement used emphasized the implication of industry-academy collaboration and practice-oriented courses, and introduced inquiry-based instructional strategy. The holistic course included lectures, game script planning, discussions and interactions with experts in IT, practical exploration and procedural design, and presentation of project results. The entire program was run for two semesters and about 21 instructors participated in this study.

The courses were implemented and measured in three stages: (1) curriculum planning, (2) teaching and learning, and (3) practice and examination. For curriculum planning, the core teaching objectives and content outlines of the courses offered in this study were determined by college instructors who had consulted industry experts. For teaching and learning, the practice-oriented courses were taught through team teaching or seminars coupled with teaching activities conducted by instructors in corresponding departments. Lastly, for practice and examination, learning outcomes were measured jointly by the industrial and educational circles based on students' performances during internship or final presentation.

This study collected and analyzed both quantitative and qualitative data. Based on the evaluation model proposed by Kirkpatrick and Kirkpatrick (2007), a course satisfaction survey was administered (measured using a 5-point Likert-type scale with 1 being the lowest point and 5 being the highest point; Cronbach's α is equivalent to .89) to gather quantitative data and utilized frequency distribution and means to analyze the data. The course satisfaction survey has 8 items and 3 open-ended questions. In addition, students' learning feedback and instructors' teaching feedback were collected for qualitative data analysis. During qualitative data analysis a triangulation and cross-case inductive analysis was conducted to confirm the reliability and consistency of the data analyses and results (Bogdan & Biklen, 1982; Guba & Lincoln, 1999; Patton, 1999; Silverman, 2000).

Results and Discussion

During the implementation of the IT program, this study integrated cloud computing technology and the implication of the living smart course, and trained students in functional requirement analysis, specification, program development, and software-hardware integration to cultivate their system integration and innovation ability. Competition and practical projects were utilized as a learning outcome measurement. Instructors were asked to plan the teaching content and paradigm for their lectures in advance to help students understand the structure of application systems and the use of function modules. To measure the learning outcome, students were encouraged to design questions by themselves or discuss them with the instructors. This trained students to design function modules on their own or develop new application systems. After they finished their work, they were given an opportunity to learn from each other before the presentation of the final results which were rated by industry experts.

Feedback from students and instructors on practice-oriented courses were collected after the implementation of the holistic course program. All participants respond to the survey and qualitative questions, and the response rate is 100%. The Means and the Standard Deviations of program satisfaction by students and instructors are shown in Table 1. The students' and instructors' satisfaction were rated 4.15 and 4.20 (based on a 5-point Likert-type scale) respectively. The results showed that both students and instructors approved of the IT program.

Table 1. The means and the standard deviations of program satisfaction by students and instructors

Group	*N*	*Mean*	*SD*
Students	73	4.15	0.67
Instructors	21	4.20	0.59

In addition to the formal curriculum, two industry-academy interaction workshops were held to deepen students' professional practice and inquiry ability. The practical courses taught by industry experts could expand students' various practical abilities, improve their understanding of the application of smart cloud monitoring and the trend of cloud computing industry, and promote their abilities to establish ties with enterprises.

The Means and the Standard Deviations of workshops satisfaction by students are shown in Table 2. The average students' satisfaction rate was 4.35 (based on a 5-point Likert-type scale), which indicates that students were satisfied with the industry-academy interaction workshops. In addition, instructors also showed positive responses to the training method. Instructor Benjamin stated:

> This program not only presented how practical products are developed in the industrial circle, but also provided students with the chance to practice the whole production process of remotely controlled aircraft, and allowed them to finish the trial flight. Further, inviting industry experts as lecturers was conducive in learning practical abilities because their experiences could help students understand work ethics better and adapt to various work pressure.

Table 2. The means and the standard deviations of workshop satisfaction by students

Group	*N*	*Mean*	*SD*
Students	73	4.35	0.72

Moreover, the course plan also included a trip to visit the industry. Students were organized to visit an exhibition center. The on-site visit aimed at helping students understand the industrial environment, equipment, and products. The staff on duty was tasked to explain workplace processes which enhanced students' understanding of what occurs in the industry and the developmental trends. During industry visits, students experienced many applications for the Internet of Things in the SIGMU's exhibition center (SIGMU is a security enterprise group in Taiwan) at the Neihu District, Taipei, including smart e-mail, intelligent parking system, earthquake early warning service system, and various interesting devices for smart living.

The Means and the Standard Deviations of field trips satisfaction by students are shown in Table 3. The average students' satisfaction rate on the tour was 4.70 (based on a 5-point Likert-type scale), which indicates that students were highly satisfied with the industry visit. Some of the feedback provided by the students included: "*I now know SIGMU better and the Internet of Things makes life very convenient", "I learned how to use mobile devices and the Internet to manage my life* "; "*I understood the use of the Internet of Things in the market*". In addition, instructor Robert stated, "*The knowledge shared by the industry can enhance students' understanding of enterprises, increase the probability for industry-academy cooperation, and strengthen the communication between the academy and the industry."* It is clear that both the quantitative and qualitative feedback from students and instructors were concurrent; both approved of the above industry visits.

Table 3. The means and the standard deviations of field trips satisfaction by students

Group	*N*	*Mean*	*SD*
Students	73	4.70	0.78

An exhibition was held at the end of the term for students to display their achievements in practice-oriented courses and projects. This open method provided an opportunity for them to observe others' results and learn from each other, and helped them improve their learning outcome. A total of 15 groups presented mobile game applications as projects in the exhibit. This hands-on training could help students effectively integrate theory and practice. In addition, both students and instructors showed affirmative and positive responses to the results-sharing training method. Instructor William mentioned:

> The project-oriented achievement exhibition utilized in this study enabled students to learn by through action. They were allowed to design the mid-term and final projects on their own, including the designs and functions of the applications. This shows that through appropriate curriculum articulation and applied design, design and programming can be integrated as one course.

Apart from attending the project achievement exhibition, students also joined and presented their works in the competition held by enterprises and achieved good results. For example, one project entitled *"The Study and Establishment of Pseudo-Hologram System",* won the second prize in the *SYSTEX Cup Apps Creativity Contest*. In addition, another project also achieved second place in the *Wheeled Mobile Robot Tracking-Lego Group A* category in the *2016 Asia Intelligent Robots Competition.* This means the practical training can significantly enhance students' knowledge and skills in Information Technology. One of the students who participated in the intelligent robots competition stated:

> With the injection of project funds, we were able to use the latest Lego Mindstorms to conduct experiments. This helped us improve our practical ability and integrate electro-mechanical knowledge and skills which enabled us to obtained good results in the robot competition.

As can be observed from the above discussion, this curriculum program utilized a practice-oriented and inquiry-based teaching method. After taking practical courses and participating in relevant activities, students were able to create excellent works and achieved good results in a professional competition. The findings are consistent with the findings of Chang & Yang (2014), Cheng, Yang, Chang, & Kuo (2016), Lai & Sheu (2016), and Lo & Lee (2014). The recognition from the industry field indicates that the program could improve not only students' practical ability but their willingness to learn and take responsibility for their own learning. In addition, through industry-academy interaction and industry visits, students could contact the industry in advance and have a chance to communicate with enterprises and learn from them. This experience could help them decide future career development and could stimulate their eagerness to be employed upon graduation. The results showed that the curriculum program provided benefits for students and improved their STEM knowledge and skills.

Conclusion

The purpose of this study was to explore whether or not the inquiry-based teaching method is effective in improving undergraduates' STEM academic performances. A curriculum program that employed industry-academy collaboration and an inquiry-based teaching method was utilized in this study to help implement knowledge-action integration in higher education and improve students' knowledge and skills in industry-academy practice. The results showed that students had affirmative and positive feedback on the program. Additionally, they were also satisfied with industry-academy interaction workshops and industry visits.

After completing the program, students were able to design a mobile game application which was an indication that students' performances in acquiring knowledge and skills in Information Technology and STEM have enhanced. Furthermore, improvements in practical exploration, and the willingness to learn and take responsibility for their own learning were also observed. Based on the results, this study held that the training in practical exploration was indeed conducive in advancing college students' STEM academic performances. Therefore this study recommended the use of industry-academy collaboration and an inquiry-based teaching method should be further promoted.

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References

Barry, N. B. (2014). The ITEEA 6E learning by DeSIGN model. *Technology and Engineering Teacher, 73*(6), 14-19.

Bogdan, R. C. L. & Biklen, S. K. (1982). *Qualitative research for education: An introduction to theory and methods*. Newton, MA: Allyn & Bacon.

Bybee, R. W. (2010). Advancing STEM education: A 2020 vision. *Technology and Engineering Teacher*, *70*(1), 30-35.

Chang, C. C. (2013). Cultivate eligible talents through instruction. *Higher Education, Technological & Vocational Education Newsletter, 81*, 29-31.

Chang, C. F. (2013). Guide for stream teaching. *Higher Education, Technological & Vocational Education Newsletter, 81*, 26-28.

Chang, J., & Tseng, Y. (2014). The implication of the apprenticeship in Switzerland for the reform of higher technical and vocational education in Taiwan. *Bulletin of Educational Resources and Research, 63*, 77-101.

Chang, K., & Li, B. (2014). Problems and prospect for talent cultivation in technical and vocational education. *Educational Resources and Research, 112*, 53-76.

Chang, K., & Yuan, Y. (2014). The status, problems, and solutions of knowledge-action integration in Taiwan. *Journal of Education Research, 248*, 5-22.

Chang, Y. N., & Kuo, C. (2008). The study for management mechanism of cooperative education. *School Administrators Bimonthly, 53,* 82-100.

Chang, Y. S., & Yang, Y. (2014). An exemplar of STEM teaching design-Hydraulic arm. *Technology and Human Education Quarterly, 1*(1), 2-17.

Chen, C. H. (2014). Human resource development policy in Taiwan. *Educational Resources and Research, 112,* 1-24.

Chen, C. L., & Lin, M. (2012). A critical thinking on the marketization of higher education. *Taiwan: A Radical Quarterly in Social Studies, 89*, 269-280.

Cheng, P., Yang, Y., Chang, S., & Kuo, F. (2016). 5E mobile inquiry learning approach for enhancing learning motivation and scientific inquiry ability of university students. *IEEE Transactions on Education, 59*(2), 147-153.

Chiu, C., Hsu, Y., & Teng, C. (2015). Reverse learning path to implement knowledge-action integration in various ways. *Evaluation Bimonthly, 54*, 22-26.

Council for Economic Planning and Development (2012). *Plan for reducing the gap between learning, training, examination, and employment*. Taipei: Council for Economic Planning and Development.

Duran, M., Höft, M., Lawson, D. B., Medjahed, B., & Orady, E. A. (2014). Urban high school students' IT/STEM learning: Findings from a collaborative inquiry- and design-based afterschool program. *Journal of Science Education and Technology, 23*(1), 116-137.

Fan, S., & Yu, K. (2016). Core value and implementation of the science, technology, engineering, and mathematics curriculum in technology education. *Journal of Research in Education Sciences*, *61*(2), 153-183.

Guba, E. G. & Lincoln, Y. S. (1999). Establishing trustworthiness. In A. Bryman & R. G. Burgess (Eds.) *Qualitative research, vol. 3* (pp. 397-444). Thousand Oaks, CA: Sage.

Kirkpatrick, D. L., & Kirkpatrick, J. D. (2007). *Implementing the four levels: A practical guide for effective evaluation of training programs***.** San Francisco: Berrett-Koehler Publishers.

Kuo, T. (2014). The challenges and reform strategies in higher education in Taiwan. *Bulletin of Educational Research, 6,* 61-72.

Lai, C. C., Tsai, S., & Yeh, C. (2015). Enhancing graduate students' competencies in designing training programs using an instructional model-based on industry-university cooperation with application of e-mentoring. *Curriculum & Instruction Quarterly, 18*(1), 213-236.

Lai, C. S., & Sheu, J. (2016). The use of practical inquiry to improve students' learning on information technology. Paper presented at *2016 Shuangxi Teaching Forum and Academic Conference*. Taipei: Soochow University.

Lee, Z. (2013). Create a practice-based teaching environment. *Higher Education, Technological & Vocational Education Newsletter, 81*, 14-15.

Liu, D., Wu, J., Hsieh, Z., & Shen, J. (2013). STEM, STEAM courses, and potential practical paths. *Information Technology Education of Primary and Secondary Schools, 6,* 39-41.

Lo, T., & Lee, P. (2014). Application of multi-inquiry teaching method with smart devices in personnel training for property management. *Journal of Property Management, 5*(2), 1-9.

Lou, S., Tsai, H., & Tseng, K. (2011). STEM online project-based collaborative learning for female high school students. *Kaohsiung Normal University Journal, 30*, 41-61.

Niu, F. (2014). Matching knowledge and skills in higher education talent cultivation: International experiences and lessons*. Journal of Education Research, 248*, 42-57.

Oyana, T. J., Garcia, S. J., Haegele, J. A., Hawthorne, T. L., & Morgan, J. (2015). Nurturing diversity in STEM fields through geography: The past, the present, and the future. *Journal of STEM Education: Innovations and Research, 16*(2), 20-29.

Patton, M. Q. (1999). The nature of qualitative inquiry. In A. Bryman & R. G. Burgess (Eds.) *Qualitative research, vol. 4* (pp. 139-159). Thousand Oaks, CA: Sage.

Reeve, E. M. (2015). STEM thinking! *Technology and Engineering Teacher*, *74*(4), 8-16.

Silverman, D. (2000). *Doing qualitative research*. Thousand Oaks, CA: Sage.

Vinson, B. M., Reardon, R. C., & Bertoch, S. C. (2014). Career services at colleges and universities: A 30-year replication study. *Journal of College Student Development*, *55*(2), 203-207.

Wang, C., Huang, Y., & Hsu, K. (2017). Developing a mobile game to support students in learning color mixing in design education. *Advances in Mechanical Engineering, 9*(2), 1-6.

Wang, J. (2013). Promote stream curriculum step by step. *Higher Education, Technological & Vocational Education Newsletter, 81*, 22-25.

Wu, S. (2014). Enhance students' employability skills: A new opportunity for knowledge-action integration. *Evaluation Bimonthly, 49*, 57-58.

Yang, Y. (2013). Improve the development mechanism of practice-based courses. *Higher Education, Technological & Vocational Education Newsletter, 81*, 12-13.

Yu, C. (2013). The cultivation of practice-oriented researchers. *Higher Education, Technological & Vocational Education Newsletter*, *81*, 18-21.

Zhu, J. (2013). The ideal face of future learning. *Higher Education, Technological & Vocational Education Newsletter, 81*, 8-11.

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