TÜRK FEN EĞİTİMİ DERGİSİ
Yıl 15, Sayı 3, Eylül 2018

Journal of
TURKISH SCIENCE EDUCATION
Volume 15, Issue 3, September 2018

http://www.tused.org

Lesson Study in Eritrea: Its Impact on Middle School Science Teachers' Learning and Classroom Practice

Ali Suleman ABDELLA[1], Chris REDDY[2] and Arend CARL[3]

[1]Doctoral student who completed his studies in 2015, Department of curriculum studies, Stellenbosch University, Stellenbosch-SOUTH AFRICA, ORCID ID: 0000-0001-9602-6050
[2]Department of curriculum studies, Stellenbosch University, Stellenbosch-SOUTH AFRICA
[3]Department of curriculum studies, Stellenbosch University, Stellenbosch-SOUTH AFRICA

Received: 29.10.2016 **Revised:** 16.10.2017 **Accepted:** 19.07.2018

The original language of article is English (v.15, n.3, September 2018, pp.1-26, doi: 10.12973/tused.10234a)

ABSTRACT

This research explores effects of lesson study on science teacher learning and classroom practice in three purposively selected middle schools of Eritrea. An extended teacher development program that combined training workshops with actual practising of lesson study contributed in enhancing conceptual understanding and pedagogical skills of teachers. The participants valued lesson study as worthwhile teacher development strategy because it brought teachers together and hence significantly contributed in minimising teacher isolation. The finding of this research provides new insights into teacher professional development in Eritrea concerning implementation of lesson study as professional development process for science teaching.

Key words: Eritrea; teacher development; lesson study; teacher learning; classroom practice

INTRODUCTION

The country Eritrea[1] has a long history of colonisation which extends as far back as the 1800's and which included various colonisers. The country eventually gained independence in 1993. This research is linked to education changes following independence. Pankhurst (1972) associates the introduction of Western-styled education in Eritrea with the arrival of missionaries in the late nineteenth century. From the colonial period to date, education in Eritrea experienced a series of reforms. The successive colonisers and the post-independence government of Eritrea reformed education to promote their agendas (Ghebremuse, 2004). The two most recent reforms took place after liberation, in 1993 and

Corresponding author e-mail: alisuleman2004@gmail.com
© ISSN:1304-6020

[1] Eritrea is a small country located in North East Africa. It shares borders with Djibouti, Ethiopia, Sudan, Saudi Arabia and Yemen.

2002. These reforms aimed at addressing the inequalities and inefficiencies in education through rehabilitating the war damaged schools, revising the curricula and expanding it to satisfy the needs of independent Eritrea. This expansion of education led to shortages of teachers at all levels, which in turn forced the Ministry of Education to employ unqualified teachers into the system (Ministry of Education, 2009).

The reforms expected teachers to shift their teaching to student-centred approaches. In addition to the requirements of reforms that differed from the practices that the teachers in Eritrea are accustomed to, teacher development opportunities are less frequent and, if any, are often organised in traditional formats. Theoretically, it was assumed that teachers who receive training through these traditional formats are expected to pass the knowledge and skills gained during the training to colleagues in their schools. Studies indicated that such type of traditional approaches produced little changes in classrooms (Lieberman, 1995; Reddy, 2004). In addition to the professional development opportunities being less frequent and being arranged in traditional formats, teachers in Eritrea work in isolation. Such isolation is assumed to restrict efforts to improve classroom practices.

Lesson study can become an alternative way to bring changes in the context of teaching and learning in Eritrea. Stigler & Hiebert (1999) stated lesson study, a form of teacher professional development originated in Japan, as a key factor in improvement of mathematics and science education. Lesson study involves small groups of teachers meeting regularly to engage in a collaborative process planning, teaching, evaluating and refining of lessons (Lewis 2002a; Lewis 2002b). Chassels & Melville (2009) found that lesson study provides opportunities for teachers to build professional learning communities, to deepen understanding of curriculum and pedagogy, and to develop habits of critical observation, analysis, and reflection. Fernandez (2005) also identified that teachers who participated in lesson study shifted their teaching to a more student-centred pedagogy. As supported in the literature, this research utilised lesson study as a strategy to support teachers and bring them together to collaborate and share experiences in order to improve their classroom practices (Hiebert, Gallimore & Stigler, 2002).

Purpose and Research Questions

The purpose of this research was to try lesson study in three middle schools of Eritrea and then explore its effects on learning and classroom practices of science teachers. One main and three sub-research questions guided the study. The questions were developed based on the work of Guskey (2000). Guskey's (2000) model was appropriate because of its wide acceptance in the field of education, which implies that any conclusions drawn can be considered valid.

(1) What is the effect of lesson study on learning and classroom practice of middle school science teachers in Eritrea?
   (a) What are reactions of teachers to the professional development arrangement?
   (b) To what extent did teachers who used lesson study in their classrooms gain knowledge and skills?
   (c) To what extent did teachers who used lesson study apply the knowledge and skills gained into their teaching?

What is Lesson Study?

Lesson study began in Japan. It is a well-established classroom-based and collaborative form of teacher development strategy (Lewis & Tsuchida, 1998; Lewis, Perry, & Hurd, 2009; Murata, 2011; Stigler & Hiebert, 1999) used by teachers to systematically examine their practice to become more effective teachers (Fernandez & Chokshi, 2002).

According to Stigler and Hiebert (1999), lesson study is a collaborative approach of planning, teaching, observing, revising and re-teaching of lessons. Teachers who experiment with lesson study will identify a topic that they want to teach by conducting series of discussions on several issues such as the alignment of the topic to the curriculum, the strengths and weaknesses in student learning, and the strengths and weaknesses in their teaching strategies and means of improving them (Watanabe, 2002). After identifying a topic, teachers collaboratively plan a lesson and when one teacher teaches the lesson, others examine and observe it to gather relevant data for its improvement. The next step is reflecting on the lesson as a team. Following the discussion, another team member teaches the revised lesson to another group of students if the team members decide to revise and improve the lesson. The re-teaching is followed by a second debriefing session (Lewis, 2002b). Lesson study is distinguished from other forms of teacher development strategies because its focuses on a lesson not on the teacher who taught the lesson, on observing student learning not on the individual teacher performance and on collective work not on the individual performance of teachers (Stigler & Hiebert, 1999; Rock & Wilson, 2005; Puchner & Taylor, 2006; Stepanek, Appel, Leong, Mangan, & Mitchell, 2007).

Steps of lesson study

Lewis (2002b) divides the activities of lesson study into three categories: identifying a long-term goal or topic, teaching the lesson to explore the goal, and reflecting on the process. The first activity can be established by looking at the gaps between where the students are in their learning experience and what the teachers expect for their students (Lewis, 2002b; Watanabe, 2002). The second activity is accomplished by a team of teachers coming together to prepare a detailed plan on what and how to teach. When one teaches the lesson, other team members observe it. At last, teachers engage in reflection process (Lewis, 2002b). Reflection often focuses on the research lesson and not on the teacher who taught the lesson (Puchner & Taylor, 2006; Rock & Wilson, 2005; Stepanek, et al., 2007; Stigler & Hiebert, 1999).

A five-step cyclical model was developed for this study (see Figure 2). These steps are forming lesson study groups, selecting a suitable topic, planning a research lesson, teaching and observing research lesson, and reflecting and re-teaching a research lesson. The lessons taught during lesson study are known as research lessons (Chokshi & Fernandez, 2005; Lewis, 2002a, 2002b; Murata, 2011). They are different from ordinary lessons because they are collaboratively planned, observed, recorded and discussed by a group of teachers who share common objectives (Lewis & Tsuchida, 1998).

In summary, publication of Stigler and Hiebert (1999) inspired many educators to use lesson study. Since then lesson study has spread substantially and experimented in many countries. There are reports of successes that cannot be ignored. It is believed that if teachers in Eritrea participate in lesson study, they would be able to improve their classroom practices because its collaborative nature will allow them to share ideas, observe and provide feedback to one another. Thus, the researchers experimented with lesson study in selected middle schools to create a professional development opportunity for science teachers. The structures of professional development are wide and varied. In the next section, teacher professional development is conceptualised in brief.

TEACHER DEVELOPMENT AND LEARNING

Teacher development refers to a continuing learning process that starts with initial teacher education, followed by induction and then culminating with continuing teacher development (Earley & Bubb, 2004; Feiman-Nemser, 2001). The latter stage is the focus of this research as indicated in Figure 1.

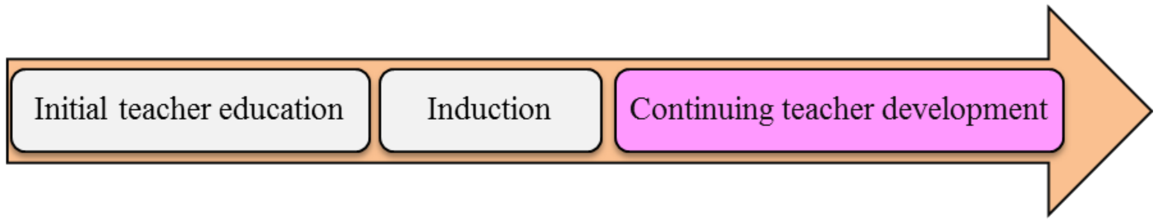


Figure 1: Teacher development continuum Source: Abdella (2015, p. 30)

Teacher development approaches are categorised as either traditional or reform-based based on duration, form, participation, content, type of activity and coherence (Garet, Porter, Desimone, Birman, & Yoon, 2001). In this study, reform-based professional development considered as an approach that would best suit the context of Eritrea. The teacher corps in schools was not highly motivated and familiar with teacher centred approaches in which mainly textbooks are in use as resources for teaching. Teachers are accustomed to traditional professional development processes as outlined below.

Traditional approaches are often arranged in the form of short workshops, seminars and conferences (Feiman-Nemser, 2001; Little, 1993). These approaches give teachers with clearly defined body of knowledge and skills through well-structured process (Carl, 2008). However, they provide little attention to teacher statements by limiting them to mere 'recipients' of information (Carl, 2005, p. 223). Traditional approaches do not provide sufficient time for the teachers to study the presented material (Garet, et al., 2001). Since the sessions are not linked to real problems in classroom, teachers fail to connect the newly gained ideas to their contexts and thus unable to produce changes in their classrooms (Kennedy, 2005; Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2010). Moreover, these approaches lack of appropriate support and follow-up strategies (Feiman-Nemser, 2001; Guskey, 1994; Guskey and Yoon, 2009; Lieberman, 1995; Loucks-Horsley, et al., 2010) and lack of opportunities for teachers to collaborate with one another (Feiman-Nemser, 2001; Loucks-Horsley, et al., 2010).

On the other hand, the reform-based approaches are extended over a long duration of time, are school-based, allow collective participation of teachers, provide opportunities for deeper understanding of content, provide active learning opportunities, and consider professional development as integral part of teacher learning (Garet, et al., 2001). Since the traditional approaches have become ineffective and inadequate in offering the required time, content, active leaning opportunities and support for teachers, teacher development approaches recently shifted their focus towards reform-based approaches. Mentoring, coaching, study groups and lesson study belong to the reform-based category (Loucks-Horsley, et al., 2010). The characteristics of traditional and reform-based approaches of teacher development are summarised in Table 1.

Table 1: Characteristics of traditional and reform-based approaches of teacher development

Features	Components	Traditional	Reform-based
Structural	Duration	Conducted in the form of short workshops, seminars and conferences.	Arranged for longer duration in the form of mentoring, coaching, lesson study and study groups.
	Form	Focuses on transmission of knowledge to passive recipients by external experts. Usually arranged outside schools.	Oriented towards construction of knowledge by active teachers and relies on internal expertise. Usually arranged in schools.
	Participation	Directed towards individual teachers as the primary recipients.	Directed towards formation of professional learning community.
Core	Content	Offer fragmented and unrelated topics in piecemeal.	Aimed at improving and deepening teachers' content knowledge that is relevant to the day-to-day practice.
	Active learning	Focuses on passive learning.	Encourages teachers to become more engaged in discussion, planning, and practice, observing and feedback.
	Coherence	Professional development lacks relevance to the problems that teachers have at hand.	Professional development experience is part of the integrated program of teacher learning.

Source: Garet, et al. (2001)

The researchers argue that lesson study is a good choice that has the potential of providing effective and sustainable professional development opportunity for teachers in Eritrea to help them implement the reform initiatives because lesson study embodies the essential features of reform based professional development approaches discussed above (Bocala, 2015). Moreover, lesson study minimises teacher isolation by bringing teachers together to collaborate and share professional ideas and experiences (Abdella, 2015).

Transformative professional development, as indicated in the table below, formed the underlying thinking of this research. An idea from the transformative approach is that the duration is much longer than traditional processes and that there is active involvement of participants. In Eritrea, this transformative idea provides both the time and space for interaction among teachers on the programme, a factor that can assist with breaking the isolation. Active participation in lesson planning and critical discussions of the lessons taught also turns participants from passive receivers into active creators of "knowledge" in these transformative approaches of professional development. This is directly possible through lesson study.

Kennedy (2016) reviewed professional development programmes and tried to sort programs according to their underlying theories of action. The theory of action includes two important parts. The first is the main idea that teachers should learn. The other is the strategy for helping teachers enact with the idea within their own ongoing systems of practice. She reviewed research on professional development programs with an eye toward learning, more specifically, on how different approaches to professional development actually foster learning. She included questions about what teachers need to learn, what kind of professional development activities foster learning, about how learning in one context such as a professional development workshop affects behaviour in another such as a teachers' own classroom. Moreover, Kennedy highlighted the importance of programme content as well as enactment processes followed on the professional development programme as important factors that determine success of these programmes Kennedy (2016).

According to Kennedy (2016), lesson study is a process by which teachers engage in critical discussion and deliberative interactions to improve the process and develop ideas that they can implement in their own classrooms. The critical discussions and deliberative interactions link lesson study to what is considered "good" forms of professional development and highlights that lesson study has important core elements that foster teacher development.

The ideas about lesson study highlighted above are important for teacher development in Eritrea. The education system in Eritrea was largely dysfunctional after many years of war where classroom interactions are reduced to unidirectional teacher driven pedagogies. This study focuses on the possible impact of lesson study on professional development of middle school science teachers.

RESEARCH METHODOLOGY and DESIGN

a) Research design

A qualitative, inductive and exploratory case study was chosen. According to Yin (1984), case study is "an empirical inquiry that investigates a contemporary phenomenon within its real-life context" (Yin, 1984, p. 23). For Walker (1980, p. 33) the essence of case study lies in the "examination of an instance in action". An instance could either be an individual child, a classroom of children, an innovative program or a school (Stake, 1995). These definitions indicate that case study is a methodology of choice when an in-depth investigation of a phenomenon is required as in the case of this study. This research is a collective case study that took place in three separate middle schools (Stake, 1995) and with clear boundaries (Merriam, 1998; Stake, 1995). Agreeing to Yin (1984), this research is a holistic case study with a group of middle school science teachers as its unit of analysis.

A framework indicated in Figure 2 guides this research. The framework indicates that the research process took place in two steps. Firstly, the training workshops were organised to provide the participants with the concept and skills of lesson study. Secondly, teachers were allowed to practise lesson study in their classrooms for two academic semesters. In latter step, the iterations of lesson study activities that resemble action research enable the teachers to work collaboratively. The framework also shows that participating in workshops and practising lesson study at classroom level enhance teachers' learning in personal, social and professional dimensions as suggested by Bell and Gilbert (1996), which in turn contribute to teachers' change in classroom practice. These two steps, training workshops and practicing lesson study, are further discussed in subsequent sections.

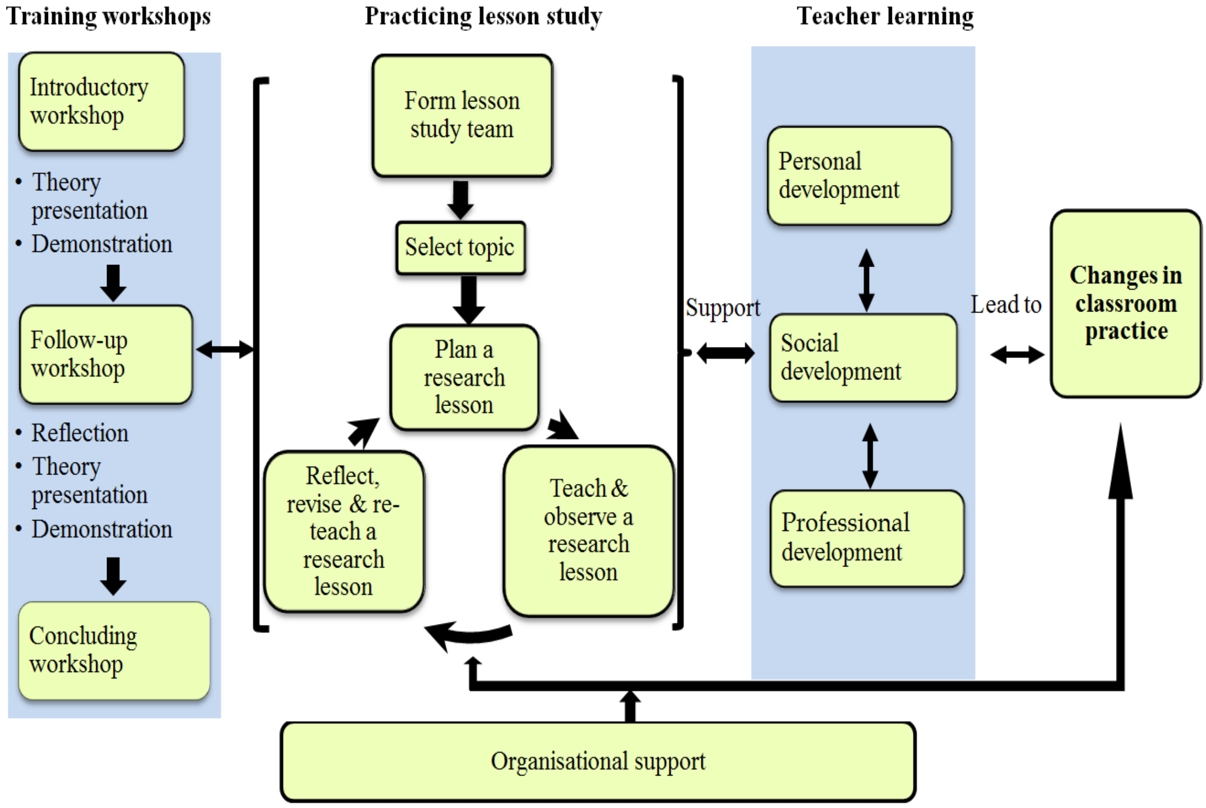


Figure 2: A framework that guided the study *Source*: Abdella (2015, p.63)

b) Lesson study training workshops

Participants received trainings on lesson study during the introductory and follow-up workshops (see Figure 2 and Table 2). These workshops contained presentation of theory and demonstration of lesson study skills as their components (Joyce & Showers, 2002). The presentations of theory were aimed to acquaint teachers with the concepts underlying lesson study whilst the demonstration (using video clips[2]) sessions to provide visual support on how to conduct and implement lesson study in classrooms (Joyce & Showers, 2002). The concluding workshop was aimed to formally end the process and convey words of thanks to all the participants.

[2] The videos were downloaded from lesson study sites https://www.collaborativeclassroom.org/lesson-study and https://www.youtube.com/watch?v=0xgko79kO94

Table 2. Structure and components of training

Duration	**Structure**	**Components**
First semester (23 Feb - 29 Jun 2013)	Introductory workshop	Theory presentation Demonstration of lesson study skills
	Practicing of lesson study	Practising lesson study Guidance and support Organisational support Support from Knowledgeable-other
Second semester (02 Sep - 31 Dec 2013)	Follow-up workshop	Theory presentation Demonstration of lesson study skills
	Practicing of lesson study	Practising lesson study Guidance and support Organisational support Support from Knowledgeable-other
End of the project	Concluding workshop	Thanking and distributing certificates

Source: Joyce and Showers (2002)

c) *Data generation*

Multiple instruments were used to generate data namely through questionnaires, semi-structured focus group interviews and through documents generated during lesson study events. Using multiple data generation methods ensured methodological triangulation as suggested by Patton (2002). Biographical information was obtained using a questionnaire (D) prepared to that effect. Another questionnaire (E) was administered to obtain participants' reactions towards the workshops. Three focus group interviews (H1, H2, and H3) were conducted with the teachers at different stages of the lesson study process. One focus group interview (J) was conducted with the school principals and pedagogic heads at the end of the process. All interviews were conducted in local language. The interviews were first transcribed and then translated into English. The teachers were requested to report their experiences of the lesson study process on formats designed to generate data (F, G and L). They reported their experiences during observation sessions (F), after debriefing sessions (L) and end of lesson study cycles (G). The teachers were requested to respond to these documents in either English or local language.

Data obtained through these instruments were made available for data analysis. The first author recorded field notes during observations, interviewing and discussions held with the participants. These field notes were not coded and analysed. However, they were used to supplement the data analysis. In addition to the methods that generated textual data, video and photographic media were used to capture the details of the natural settings and activities of the research. These video and photographic data were neither coded nor analysed but used a supplementary source of information, as they provide powerful stimuli to recall the setting.

Credibility and trustworthiness was ensured, during conducting of the research and reporting of the findings, through prolonged engagement at study site, triangulation, collection of referential adequacy materials, description of context, and peer debriefing (Guba, 1981; Lincoln & Guba, 1985; Merriam, 1998; Mertens, 1998).

d) Participants

This research was undertaken in three purposively selected middle schools (Cohen, Manion, & Morrison, 2011; Merriam, 1998) from Zoba Maakel region of Eritrea. Fifteen science teachers volunteered to participate in this research. In addition to the teachers, one school principal and one pedagogic head from each school participated in the study. Pseudonyms were used to protect the anonymity of the participants and the schools. The names of the teachers were coded as T1, T2, T3, T4, T5 and T6, school principal as P and pedagogic head as PH. The schools were named as "A", "B", and "C". Table 3 summarises the background information of the participants.

Table 3: Participants' background information

School	Teacher	Gender	Age	Qualification	Teaching load/ week	Participated in workshops	Years being a teacher	Years at this school	Grade currently teaching
A	SAT1*	M	60 +	Diploma[3]	18	Yes	40	15	8
	SAT2	M	60 +	12+1[4]	18	Yes	39	3	8
	SAT3	M	20-29	Diploma	18	Yes	5	5	7
	SAT4	F	40-49	Diploma	24	Yes	26	6	8
	SAT5	F	20-29	Diploma	21	Yes	4	4	7
	SAT6	M	50-59	12+TTI[5]	18	Yes	34	16	7 & 8
B	SBT1*	M	30-39	Diploma	18	No	7	4	8
	SBT2*	M	30-39	Diploma	18	No	14	1	6
	SBT3	M	60 +	Diploma	18	Yes	43	3	8
	SBT4	F	20-29	Diploma	18	No	2	2	8
	SBT5	M	50-59	Diploma	18	Yes	36	1	8
	SBT6	M	20-29	Diploma	24	Yes	4	4	6
C	SCT1*	M	50-59	Diploma	24	Yes	35	3	8
	SCT2	F	40-49	Diploma	24	Yes	24	2	7
	SCT3	M	30-39	12+TTI	28	Yes	11	1	6

*Head of departments

Table 3 indicates that four (27%) of the teachers were females and 11 (73%) were males. In terms of age, teachers in Schools "A" and "C" were older than teachers in School "B". Two third of teachers in Schools "A" and "C" and one third of teachers in School "B" were older than 40 years of age. Regarding teaching experience, teachers in Schools "A" and "C" were more experienced than teachers in School "B". Four out of six teachers in School "A", half of teachers in School "B", and all teachers in School "C" had more than ten years of

---

[3] Diploma is the minimum qualification requirement for teaching in middle schools of Eritrea.
[4] 12+1 stands for a one-year university level education after completion of secondary school. Such teachers are not trained to be teachers.
[5] 12+TTI stands one year at certificate programme at Teacher Training Institute (TTI) after completion of secondary school level. Such teachers are trained to teach in elementary school level and are unqualified to teach in middle school level.

experience. In terms of qualification, all teachers in School “B” were qualified to teach in middle schools, because they had a diploma from college of education, a minimum requirement to teach in middle schools of Eritrea. One third of teachers in Schools “A” and “C” have no credentials required to teach at middle school level. Concerning teaching workload, teachers in School “C” had higher teaching workload than teachers in Schools “A” and “B”. In terms of participation in professional development processes, all teachers in Schools “A” and “C” indicated that they had participated in some form of professional development opportunities. However, half of the teachers in School “B” did not have any chance of participating in professional development processes. Those who had the opportunity, indicated that the professional development focussed on issues such as methods of teaching, student-centred and interactive pedagogy, questioning skills, special needs, lesson planning, classroom management, orientations on new curriculum, utilisation of laboratory and continuous assessment.

e) Practicing of lesson study

Following the workshops, the science teachers were allowed to practise lesson study in their respective schools. Five steps were followed during practicing of lesson study (see Figure 2). Forming lesson study team was the first step of lesson study process. Stepanek et al. (2007) suggest that multiple perspectives are ensured by having a minimum of three members in lesson study teams. They warn that having more than six members may pose a problem of getting common time when all group members are available. In the second step, teachers chose topics that are either difficult for their students to understand or difficult for them to teach. The third step was planning a research lesson collaboratively. Matthews, Hlas, and Finken (2009) believe joint planning enhances teacher collegiality and collaboration. Teachers used a four-column lesson plan format to plan their lessons (see Figure 3). In the fourth step, when one teacher taught the jointly planned lesson, others examined and observed it to gather relevant data for its improvement. The last step was to analyse the research lessons, as a team, based on the data gathered during observation. This step began with the teacher who taught the research lesson by detailing what parts of the lesson worked as planned and what required improvement. Based on the data that they have collected, the other team members forwarded their feedback for improving the research lesson (Joyce & Showers, 2002; Stigler & Hiebert, 1999). Based on the discussions, they revised the research lessons and another team member taught the lesson to another group of students. The re-teaching was followed by second observation and reflection. During the second debriefing sessions, teachers reflect on whether the lessons met the goal and discussed on any necessary refinements of the lessons for their re-teaching in the future.

Learning activities	Student activities/ expected student responses	Teacher's responses to student reactions	Goal and method of evaluation

Figure 3: The four-column lesson plan format
Source: Lewis (2002b) and Matthews et al. (2009)

While practicing lesson study, the teachers received guidance and support as suggested by Joyce and Showers (2002). This was performed by establishing supportive school environment and creating platforms for teachers to come together to collaborate, share ideas, guide and coach one another. The school principals, pedagogic heads and department heads were involved to create supportive school environment for the practicing teachers. The department heads and experienced teachers within the groups played an important role in supporting and coaching their colleagues. Moreover, the first author acted as knowledgeable-other in addition to the role of a researcher. By assuming the former role, he provided training on lesson study during the workshops and guided the teachers through lesson study process. Stepanek et al. (2007) define knowledgeable-other as an individual who works and supports lesson study team members with subject matter knowledge, pedagogical knowledge and lesson study practice. The process is summarised in Figure 2 and Table 2.

RESULTS and DISCUSSION

Based on the traditions of grounded theory, thematic analysis was used to analyse the data (Auerbach & Silverstein, 2003; Charmaz, 2000; Strauss, 1987; Strauss & Corbin, 1990). The research questions were used to categorise the data and not the questions on the research instruments. The first research question was answered from data generated through questionnaire. The second and third research questions were answered from interviews and data obtained from formats designed to generate data from lesson study events.

The data analysis begun by reducing textual data obtained through the questionnaires, semi-structured focus group interviews and documents generated from lesson study events into manageable units called codes and then categorising them into data sets to look for emerging patterns as suggested by Bogdan and Biklen (2007).

Three types of coding were used, namely open coding, axial coding and selective coding (Strauss, 1987; Strauss & Corbin, 1990; Henning, Van Rensburg & Smit, 2004). Open coding, the first step in the coding process, used to break the raw data into segments called codes and then sort them into similar subcategories. This was done by listening to the interviews and reading the transcripts repeatedly sentence by sentence, line by line and word by word to generate codes inductively from the raw data. Axial coding, the second step in the coding process, focused on the codes created during the open coding rather than on the raw data (Strauss, 1987; Neuman, 2011). It was an iterative process in which the initial codes were reviewed and examined again to generate additional ideas and codes, merge closely related concepts into one or drop some of the ideas (Neuman, 2011). The subcategories were further compared to one another and then grouped into higher order concepts to form generic categories. Finally, the generic categories were integrated to form abstract categories called main categories. The generic categories were matched to the research questions to form main categories that were mainly used to structure the presentation and discussion. This rigorous process of coding ensures validity and reliability of data produced (see Figure 4).

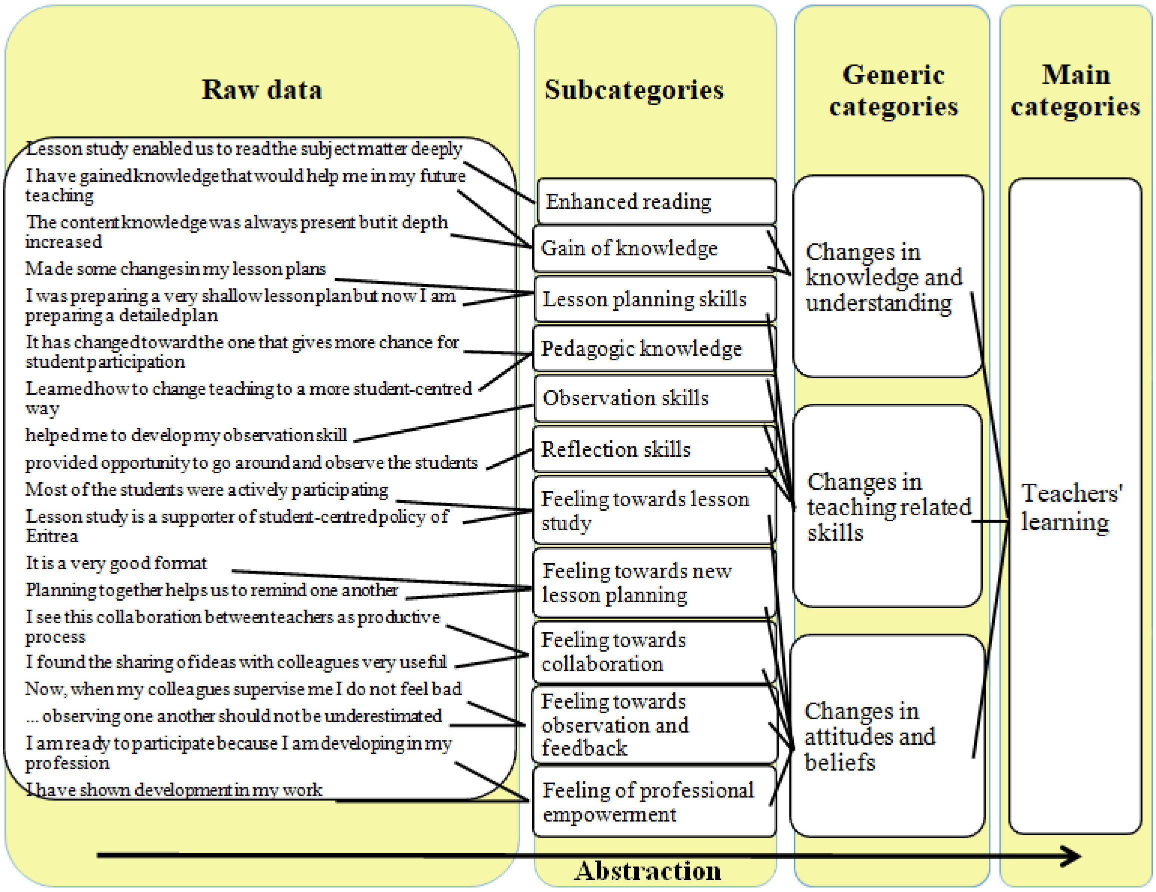


Figure 4: Example of categorisation *Source*: Elo and Kyngas (2008, p. 111)

Participants' reactions to the training workshops

The first research question was intended to measure participants' reactions to the workshops. The initial satisfaction of teachers with the context, process and content is fundamental to higher level learning (Guskey, 2000). The reaction of participants towards the training workshops was obtained through a questionnaire and the results are categorised into context, process and content (see Table 4). Firstly, the context deals with whether the participants were satisfied with the food and drinks and comfort of the workshop settings. The results revealed that most of the participants valued the contexts in which the workshops were conducted. They appreciated the food and drinks served during the workshops. They also described the workshop settings as well-lighted, quiet and within travel distance.

> It was enjoyable because there was enough time to break, enough water and good lunch (SAT3-E)
> The place was suitable […] and it was quite place and there was no sound that distracts us. (SAT1-E)
> […] distance of the venue was suitable. (SAT6-E)

However, a pedagogic head from School "B" indicated that the workshop setting was not suitable for group discussion as the noise of one group created distractions as the groups were in hearing distance from one another.

Narrow to discuss freely without noise. (SBPH-E)

Table 4. Summary of the results

Main categories	Generic categories	Subcategories
Participants' reactions	Reactions to context, process and content of workshop	Context of workshop Process of workshop Content of workshop
Teachers' learning	Change in knowledge and understanding	Enhanced reading Gain of knowledge
	Change in teaching related skills	Pedagogic knowledge Lesson planning skills Observation skills Reflection skills
	Change in attitudes and beliefs	Feeling towards lesson study Feeling towards new lesson planning Feeling towards collaboration Feeling towards observation and feedback Feeling of professional empowerment
Teachers' use of new knowledge and skills	Change in teaching methods Increased use of teaching-learning resources Collaborative work Peer observation	

Secondly, the process deals with whether the organisation of the workshops made sense and whether the organisers were knowledgeable and helpful (Guskey, 2000). All the participants appreciated the organisation of the workshops. They appreciated the theory presentation and the video demonstration sessions. They also founded the expertise of the organisers to be effective.

It was effectively organised. (SBP-E)
[…] all the sessions were effective. (SBT3-E)
Good facilitators. (SAT2-E)

On the other hand, some participants from Schools "A" and "C" indicated that the introductory workshop interfered with their Saturday schedule which they could earn some extra income.

It clashed with Saturday classes of many teachers. (SAP-E)

Finally, the content refers to the usefulness of the materials and the presentations. The majority of the participants indicated that they have acquired new knowledge and skills. They also appreciated the idea behind lesson study because they expected lesson study to enhance teamwork, their teaching and student learning.

We came to know new knowledge that we did not know it before. (SAP-E)
The workshop was very useful because I got new information and knowledge. (SBT2-E)

However, teachers unanimously indicated that the workshops were short in duration to fully equip them with necessary knowledge and skills. They recommended for longer workshops in the future when similar workshops are held.

> The time given for the workshop was very short. (SCT1-E)
> Rushing was observed in order to cover all the topics (SAT3-E)

After attending the workshops, the participants indicated their confidence to practise lesson study in their classrooms as follows:

> I am confident that I will be able to implement what I have learned (SAT3-E)

Although the participants found the workshops to be effective and helpful, much of the literature are sceptical about the effectiveness of such workshops (Feiman-Nemser, 2001; Fullan, 2007; Guskey, 1994; Guskey & Yoon, 2009; Kennedy, 2005; Lieberman, 1995; Loucks-Horsley, et al., 2010). The reason why the participants valued and described the workshops as effective could be due to three reasons. Firstly, teachers in Eritrea rarely participate in such professional development strategies. Secondly, the activities of the workshop were organised based on an effective professional development model that allowed active participation of the teachers (Garet, et al., 2001), relevant to the day-to-day practice of teachers (Guskey, 2000), and organised based on teachers' identified needs (Loucks-Horsley, et al., 2010; Sparks, 2002). Finally, a framework that combined workshops with classroom practices was designed instead of using workshops alone. Combining two or more strategies provided teachers the opportunity to apply in their classrooms what they have learned at the workshops as supported in the literature (Kennedy, 2005; Loucks-Horsley, et al., 2010). Hence, the participants reported their satisfaction with the arrangement and organisation of the workshops.

Impact of lesson study on teachers' learning

The second research question focuses on learning gains of teachers. Three generic categories namely change in knowledge and understanding, change in teaching related skills and change in attitudes and beliefs were identified from the data analysis, (see Table 4).

Change in knowledge and understanding

All teachers from Schools "A" and "C" and the majority of the teachers from School "B" reported that participating in lesson study improved their conceptual understanding through reading books, peer observation, and collaborative work. They further indicated that the peer observations and collaborative works enabled them to share ideas and learn from one another. This finding is consistent with the findings of Fernandez (2002) and Rock and Wilson (2005) where teachers who used lesson study learned more content as a result of collaborative planning, teaching, observing, revising and re-teaching of lessons.

> Lesson study helped me to have deep knowledge about the subject matter […] because […] I referred to several books in order to prepare for the lessons. (SAT3-G3)

Most of the teachers who participated in this research considered themselves as learners and acknowledged that they have learned by participating in lesson study. However, two teachers from School "B" indicated that they have not gained new knowledge by participating in lesson study as illustrated in the extract taken from end of lesson study cycle reporting format.

> No changes in the knowledge of subject matter. (SBT4-G1)

Unlike the teachers who indicated that they have learned from the lesson study process, these teachers seemed to view themselves as complete professionals who do not require additional knowledge. It was observed that these teachers did not want to be perceived as learners. They were reluctant to indicate that they have gained new knowledge related to subject matter. This may be because these teachers wanted to maintain their self-image or did not want to be perceived as less competent. Unlike the teachers who search for new information, such teachers are prone to work in isolation and maintain their old attitudes and practices as indicated by Lortie (1975).

Change in teaching related skills

The teachers agreed that participation in the lesson study enabled them to develop pedagogical skills, lesson planning, observation, and reflection as discussed below (see also Table 4).

Enhanced pedagogical knowledge: Consistent with the literature, the teachers held deeply rooted belief about teaching (Stigler & Hiebert, 1999). Before participating in lesson study, they thought that it is impossible to teach student-centred lessons because of contextual constraints that are present in Eritrean schools, such as pressure of content coverage, heavy workloads and large classes as illustrated in the following interview extracts.

> We were saying class-size is a hindrance to implement a student-centred teaching. We were also saying that 40 minutes are not sufficient for such type of teaching. Now, we used the same 40 minutes for teaching student-centred way. (SAT3-H1-00:05:41)
> Earlier, we were thinking that teaching big class-size, like our classes, using discussion method kills time. (SBT4-H2-00:11:50)

Given the limiting contexts, the teachers indicated that they used student-centred methods more frequently than before. Thus, they claimed that lesson study enhanced their pedagogical knowledge. All teachers from the three schools claimed that they have used more participatory teaching methods that gave hands-on experiences to their students. They indicated that they have shifted their role from mere providers of information to facilitators of learning and were able to organise activities that satisfy the needs of a range of students.

> After participating in lesson study, I am taking the role of facilitator and enabling the students to participate more in the learning process. (SAT2-G3)

Interview extracts of teachers also illustrate:

> In earlier teaching, we focused on how to cover the content. Now, we are thinking about what concept the students would grasp and how to achieve the goals of the lesson. (SAT3-H2: 00:09:06)

> […] we used student-centred teaching more frequently during our participation in lesson study. This is because lesson study encouraged us to use student-centred way of teaching. (SCT3-H1-00:45:31)

In an interview, a teacher from School "A" emphasised on the role of textbooks in simplifying their practising of lesson study by guiding them what to teach and how to teach as follows:

> The science textbooks are extremely good. They prescribe exactly what we were doing during lesson study. The lessons in the textbooks start with 'let us discuss' and then go to motivation. The lessons guide how to allow students to participate. The subject matters in the textbooks are related to the students' daily life activities. If we properly follow to lesson study, it will enable us to achieve the goals prescribed in the textbooks. […] What is in the textbook is what we have practiced in lesson study. This way of teaching has already been in the textbook before you brought to us. The Ministry of Education instructs us to teach that way. Lesson study has initiated us to think about implementing what is proposed in the textbooks. We are practicing to implement it now. (SAT1-H1-00:08:49)

These findings support the personal development argument of Bell and Gilbert (1996), where teachers identified that their teachings were not participatory, collaboratively designed hands-on activities that enhanced students' participation and finally indicated their satisfaction with the new teaching strategies.

Enhanced lesson planning skill: Although teachers agreed on the importance of lesson planning, they admitted that before participating in lesson study, they paid less attention to it. As a result, they prepared sketchy lesson plans as illustrated by the following comment given on the end of lesson study cycle feedback form:

> Before participating in lesson study, I was preparing very shallow and short lesson plan (SAT3-G3).

During interview, School "B" teachers indicated that they did not refer to the lesson plans once they submitted them to the authorities for fulfilling the formalities. Thus, they acknowledged that what they taught in classrooms were different from what they wrote on the lesson plans.

> Once we prepared the lesson plan, we throw it to the office and we do not refer to it again. What we teach in the class may be different from what is written on the lesson plan. (SBT3-H2-00:06:16)

After participating in lesson study, however, teachers took lesson planning process seriously and spent more time on it to prepare detailed lesson plans. As a result, they developed their lesson planning skills and produced improved lesson plans as indicated in the literature (Lewis, 2002b).

> I am preparing a detailed lesson plan in collaboration with other teachers. (SAT3-G3)
> I have started making maximum preparation. (SAT4-H1-00:15:33)

The fourth benefit of lesson study is that it leads to improved quality of lesson plans

(Lewis, 2002b). This is supported by Taylor, Anderson, Meyer, Wagner, and West (2005) who indicate that lesson study enables teachers to prepare detailed plans that facilitate student learning. This is also in agreement to the progression of personal development suggested by Bell and Gilbert (1996). Accordingly, the participants first identified deficiencies in their lesson planning and then collaboratively produced lesson plans that addressed the problems. They planned lessons that focused on how students learn rather than what they learn. Finally, they indicated their satisfaction with the new experiences of collaborative planning as well as using of the new four-column lesson plan format (see Figure 3).

> The lessons were products of our discussion on how best we could prepare and present them. As a result, we were able to prepare effective lesson plans. (SCT2-H3-00:09:00)

Contrasting to the above opinions, one teacher reported that he had not made changes in his lesson planning apart from using a different format.

> There are not many changes in lesson planning. The only difference is that we were not using table format. Using such type of lesson plan format could be considered as change. (SAT1-G4)

Overall, participating in lesson study helped teachers to develop their lesson planning skills and be able to prepare better lesson plans.

Developed observation skills: Since one of the main steps of lesson study is to carefully observe learning, participation and behaviour of students (Lewis, 2002a, 2002b), the teachers supposed that in order to be able to comment during debriefing sessions, they had to observe the lessons and record their observation carefully. As a result, they claimed that they had developed observation skills. They were able to observe subgroup formations and at the same time devise means of minimising the problem by changing the sitting arrangements of their students. They were also able to observe that their participation in the lesson study cycles improved the discipline and attentiveness in their students.

> […] a unique experience that we have practiced during lesson study was peer observation, an experience that appeared to us like climbing a mountain. We got an opportunity to observe lessons of one another. (SCT2-H2-00:21:18)
>
> I have also developed observation skill. I was able to develop a skill of explaining my observations. (SBT2-G2)
>
> I have never focused my observation to what students were doing. (SAT4-H1-00:06:58)
>
> I have never thought about creation of subgroups. After providing a task as a group work, we were assuming that all students are discussing as a single group. Now, I have learned that it is important to circulate and go around the class in order to avoid the creation of sub-grouping. (SAT5-H1-00:16:54)

Participation in the lesson study cycles helped teachers to improve their observation skills. Likewise, Lewis (2002a, b) reports that Japanese teachers developed observation skill when they observed research lessons. Bell and Gilbert (1996) describe participating in new activities such observing one another and observing students' learning as evidence of professional development. Thus, this research confirmed the goal of lesson study as a process of promoting teacher capacity of observing learning, motivation and behaviour of students as highlighted in the literature (Chokshi & Fernandez, 2004; Lewis, 2002a, 2002b).

Improved reflection skills: All teachers from the three schools indicated that lesson study provided them opportunity to reflect on their own weaknesses and strengths. Lesson study also enabled teachers to give and receive constructive feedbacks on several aspects such as use of chalkboard, use of teaching and learning resources, arrangement of desks, design of learning activity and students' participation. These reflective skills promote classroom practice since teachers participate in more lesson study cycles over time. Such effect of reflection on enhancing teaching is in accordance with the finding of Cimer and Cimer (2012).

> The content of the lesson matched the ability of the outstanding students, but it was difficult for the weak students. (SAT2-F8)
> […] the lesson was supported with real teaching aids and model e.g. car, ball and shoes and majority of the students participated in the lesson. (SBT2-L8)

Even though the teachers managed to speak publicly about their weaknesses and strengths and provide feedbacks to one another, they were observed to be more comfortable speaking about their students' learning and weaknesses rather than their own as observed in the above quotes. Moreover, the teachers were observed to be more comfortable in giving positive feedbacks than criticising their colleagues. Fernandez, Cannon, and Chokshi (2003) highlighted the inability of teachers to reflect on their own teaching practices and being unable to engage in critical dialogue about teaching learning as a common challenge to implementing lesson study. They suggest that teachers must see themselves as researchers and learn to generate powerful questions around the professional dialogue.

Change in attitudes and beliefs

The analysis of teacher responses revealed that teachers had changed their attitudes and beliefs as a result of participating in lesson study as discussed below.

Feeling towards lesson study: Data revealed that teachers had developed positive attitude towards lesson study. In the interviews, teachers described lesson study as important, supportive, enjoyable, good, useful, helpful, productive, and creative because it allowed them to come together to collaborate, share ideas, and prepare participatory learning process for their students.

> Lesson study is supportive. It helps teachers to exchange experiences. […] It encourages student-centred way of teaching, which is also necessary at this time. (SBT1-H2-00:29:55)
> Lesson study was helpful in working together, identifying problems together and then solving the problems together. (SCT2-H2-00:13:18)

A teacher from School "A" indicated that much of the changes are in their minds and not in the actual teaching practices as follows:

> I can say there is change to some extent, but much of the change is at attitude level. It is in the mind. (SAT1-H2-00:40:20)

Despite the positive feelings, teachers expressed that lack of time, heavy workload, and large class-size as potential constraints to the implementation of lesson study in Eritrea.

> […] it is difficult to implement because it takes a lot of time and we are overloaded. (SCT2-H2-00:13:18)
> […] conducting lesson study with students ranging from 40-50 and bulky load is a little bit difficult. (SCT1-H2-00:14:05)

Feelings towards new lesson planning: The analyses of responses revealed that all the teachers appreciated the joint planning process and the lesson plan format because it enabled teachers to work collaboratively and share ideas. Thus, the participants were proud that they were able to prepare better lesson plans than the ones prepared individually.

> […] we were preparing lesson plan individually but now we are planning in groups collaboratively. Therefore, the new plans became better than old plans. (SAT1-G5)
> Planning collaboratively is better than planning individually because one can obtain support from colleagues in topics that are not clear and difficult to understand. Because of working together, one would be able to prepare a better plan. (SCT1-H2-00:03:27)

This finding corroborates the finding of a research conducted by Matthews, et al. (2009), where joint planning process enhanced teacher collaboration. The participants used lesson plan format that contained four items (see Figure 3) that the teachers included in their plan, namely learning activities, expected student responses, teacher responses to student reactions and ways of assessing student understanding (Lewis, 2002b). Analysis revealed that all the teachers valued the four-column lesson plan format, because it enabled them to think and predict student responses to the learning activities and prepare appropriate reactions to the responses. This process of predicting student responses enhanced teacher lesson planning skills and enabled teachers to stick to what has been planned.

> The lesson plan […] helped us to stick to what we have planned. This makes the lesson plan format ideal for preparing teaching learning activity. (SAT1-G1)
> The new lesson plan enabled us to write our duty and the duty of the students. (SBT2-H2-00:44:28)

Although teachers appreciated the planning process and the four-column lesson plan format, they found the meticulous planning required for every lesson to be unsuitable to Eritrean schools due to several contextual constraints such as lack of time, large class-size, and heavy workload. This substantiates earlier findings by Chokshi and Fernandez (2004) and Sengul, Cetin & Gur (2008).

> Now, using the new plan would be a challenge for us taking the amount of our workload we have into consideration. (SBT2-H1-00:52:24)
> Preparing for one lesson takes a lot of space and time. (SBT4-H1-00:54:40)

Feeling towards collaboration: In accordance with the second step of Bell and Gilbert's (1996) social development, the teachers expressed their positive feeling towards working and collaborating with colleagues. They found collaborating with colleagues enjoyable and helpful than working individually because it allowed them to share ideas and learn from one another.

> From working alone, working in pairs is better. From working in pairs, working in threes is better, because a rope made up of three threads does not break easily. From lesson study, we have learned that collaborating with one another gives strength. (SCT2-H1-00:12:59)

The teachers linked their experience of collaboration to a local proverb “two heads are better than one” as corroborated in the literature (Fernandez & Chokshi, 2002).

> As commonly said since two heads are better one head, meaning lesson plans prepared by two people are better than the ones prepared by one person. They are better because they are enriched by ideas from different teachers. (SCT1-H2-00:03:27)

Feeling towards observation and feedback: The teachers indicated their positive feeling towards opening their classrooms to external observers, observing colleagues, providing feedback, and receiving feedbacks. They indicated that lesson study enabled them to engage in open and rich professional dialogues around topic selection, lesson planning, teaching method selection and preparation of teaching learning resources.

> If you ask me about my feeling of being observed by a colleague, I feel nothing, even I feel happy. Since I do not know my weaknesses and my strengths, I would learn from the one who observes my lesson. (SCT1-H3-00:07:05)
>
> At this time, no one is afraid of being observed and no one is concerned about the feedbacks. […] I do not feel bad when an external observer comes to observe my lesson. (SAT2-H2-01:21:15)

The teachers considered the feedback sessions as opportunities for learning to be able to examine their weaknesses and strengths for the improvement of the lessons and this agrees with what has been observed by Joyce and Showers (2002).

Feeling of professional empowerment: The analysis of the teacher responses revealed that they felt change, development and empowerment as a result of participating in lesson study. Similar findings have been documented in the literature where lesson study increased the confidence and sense of professional growth of teachers (Rock & Wilson, 2005).

> Now, I am using a teaching method that has been developed and evaluated by all of us. Therefore, I feel that I have changed (SAT1-G1).
>
> This sharing of ideas helped me to develop. I have showed development in my work because of sharing ideas with colleagues. (SBT4-H2-00:12:20)

As a result of these positive feelings, all the teachers volunteered to continue participating in this research. The desire of the teachers to continue in lesson study indicates that these teachers believed that lesson study had assisted them in gaining knowledge and improving their classroom practice. They also wished similar teacher development programs for themselves and other teachers.

> I would like to continue with lesson study, but the challenge that we have is getting time and our living situation. (SAT1-H2-01:34:28)
>
> I recommend lesson study not only for teachers in one school, but also for teachers from many schools teaching the same subject. (SCT2-H1-01:06:37)

After the research however, they would continue working in lesson study only if certain conditions are fulfilled, namely if their workloads are reduced, their living conditions are improved, and class-sizes are decreased as follows:

> Sufficient time should be given. Those participating in lesson study should be free from load. The participants should be given training-workshop for about one month. A person dedicated to support lesson study should be assigned. The participants should be motivated. Number of students in a class should be reduced. (SAT6-H3-01:34:02)

Moreover, they indicated that they require additional training, a coordinator who facilitates lesson study process and support from school leadership. The importance of having a facilitator who organises resources, guides, and supports teachers through the lesson study process is supported in literature (Rock & Wilson, 2005).

Impact of lesson study on teacher use of new knowledge and skills

The third research question focuses on the extent of teacher use of newly acquired knowledge and skills. More specifically, it checks whether the current teacher practices are different from what they used to do in the past (Guskey, 2000). Even though literature indicated that teachers require sufficient time to be able to internalise and adapt the newly acquired knowledge and skills to their settings (Garet, et al., 2001; Guskey, 2000), this study identified several changes in the classroom practices of teachers in a relatively shorter period. These are change in teaching methods, increased use of teaching-learning resources, collaborative work, and peer observation. All these new activities provide evidence of teacher professional development as suggested by Bell and Gilbert (1996).

Change in teaching methods

The results revealed that the teachers used mainly teacher-centred teaching styles where they considered students as passive receivers of information prior to participating in the lesson study cycles. After participating in the lesson study, they shifted their focus to student-centred teaching that gave more attention to student learning. An important component of the student-centred learning is giving students the chance to participate actively in the teaching and learning processes, resulting in increased student learning.

> […] during lesson study we used student-centred way of teaching where the students made more talk than the teachers did. (SCT1-H1-00:19:19)
> After participating in lesson study, I am taking the role of facilitator and enabling the students to participate more in the teaching and learning process. (SAT2-G3)

Increased use of teaching learning resources

The results revealed that the teachers were not using teaching-learning resources as much as required due to factors such as shortage of resources and lack of proper storage space. During this investigation, the teachers used teaching-learning resources more frequently than before by improvising them themselves either requesting their students to bring them or use their environment as a source. They claimed that the frequent utilisation of resources provided their students with concrete hands-on activities ultimately result in increased learning and interest of their students.

> In old days, we would not take extra pain to collect all these materials. We would simply continue our teaching by abandoning the demonstration altogether. (SAT1-H1: 00:22:12)
> […] we have started using teaching learning resources in our lessons. For example, when we were teaching about flower, we brought flowers from a flower garden located at the back of our school. We have never remembered this garden before. During this lesson, we also instructed our students to come to the lesson with flowers. This is one of the changes or impacts of lesson study observed in our teaching. (SBT1-H2-00:09:41)

Collaboration

Prior to their involvement in this research, the teachers planned and taught lessons alone with limited discussions on matters related to teaching and learning. Peer observation and collaboration were limited. Participating in lesson study had contributed positively in enhancing their collaboration and minimising their isolation as indicated in the following extract:

> We worked as a team during planning, teaching, and observation. During these processes, we have benefited from and shared ideas with one another. (SCT2-H3-00:28:54)
> Now, we have already started working together in preparing lesson plans and observing one another's lesson in order to share ideas with one another. (SBT3-H3-01:24:53)

The finding of this research corroborates with Puchner and Taylor (2006) that report on the positive long-term effect of lesson study on participating collaborative efforts of teachers, ultimately changing classroom practices of teachers. Similar finding is also reported from studies in South Africa where lesson study contributed positively in enhancing collaboration and reducing teacher isolation (Coe, 2010; Coe, Carl, & Frick, 2010; Posthuma, 2012).

Peer observation

The result revealed that peer observation was not common. Participation in the lesson study cycles provided them with new experience of observing one another's lessons, which also enhanced their observation skills. Peer observation promotes teachers to learn from one another and ultimately improves classroom practice as they participate in more and more lesson study cycles.

> I have worked for several years, but we have never observed one another. (SBT1-H1-00:01:18)
> […] a unique experience that we have practiced during lesson study was peer observation, an experience that appeared to us like climbing a mountain. We got an opportunity to observe lessons of one another. (SCT2-H2-00:21:18)

CONCLUSION and RECOMMENDATIONS

The purpose of this research was to implement lesson study in three middle schools of Eritrea and then explore its effects on Eritrean middle school science teacher learning and classroom practice. A research framework that combined workshops with active classroom practice of lesson study was designed to bring such development in teachers. These workshops presented the theory on lesson study and demonstrated the skills of lesson study, an organisation which is believed to have contributed to the effectiveness of the workshops. Following the workshops, the teachers practiced lesson study in their classroom supported by different role players (Joyce & Showers, 2002). The provision of these support also influenced positively the success and implementation of the teacher development initiative. As a result of such arrangements, teachers claimed that they have conceptually developed, improved their skills in lesson planning and delivering science lessons, changed their attitudes, ultimately resulting in increased learning and changes teachers in classroom practice. Participating in the lesson study cycles enabled the teachers to use student-centred teaching styles regularly, increased the frequency of using resources and enabled them to observe and learn from one another. The teachers developed their capacity to reflect on their own practice, critique the work of other teachers and provide and receive feedbacks from colleagues. This corroborates with Xu and Pedder's (2015) finding that lesson study is a powerful learning process that helps teachers develop professionally. Moreover, lesson study provided a structure for teachers to work together and share ideas, resulting in teacher learning from one another. The collaborative nature of lesson study also helped teachers to overcome sense of isolation that they often experienced.

In conclusion, the researchers propose that the adoption of lesson study in Eritrea need to be considered for teachers at all levels in order to benefit from the approach. Providing quality professional development opportunities for teachers is central for improving quality of education delivered to students. In addition to supporting teacher learning, lesson study is a viable and an effective strategy to bring teachers to collaborate and seek solutions for their pedagogical problems.

REFERENCES

Abdella, A. S. (2015). *Lesson study as a support strategy for teacher development: A case study of middle school science teachers in Eritrea. Unpublished PhD Dissertation.* Stellenbosch: Stellenbosch University.

Auerbach, C. F., & Silverstein, L. B. (2003). *Qualitative data: An introduction to coding and analysis.* New York: New York University Press.

Bell, B., & Gilbert, J. (1996). *Teacher development: A model from science education.* London: RoutledgeFalmer.

Bocala, C. (2015). From experience to expertise: The development of teachers' learning in Lesson study. *Journal of Teacher Education,* 66, 345–362.

Bogdan, R. C., & Biklen, S. K. (2007). *Qualitative research for education: An introduction to theory and methods* (5th Ed.). Boston: Pearson.

Carl, A. E. (2005). The "voice of the teacher" in curriculum development: A voice crying in the wilderness? *South African Journal of Education,* 25 (4), 223-228.

Carl, A. E. (2008). Reconceptualising teacher training at a South African university: A case study. *South African Journal of Higher Education,* 22 (1), 17-40.

Charmaz, K. (2000). Grounded theory: Objectivist and constructivist methods. In N. K. Denzin, & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (2nd ed., pp. 509-536). Thousand Oaks: CA: Sage publications.

Chassels, C., & Melville, W. (2009). Collaborative, Reflective, and Iterative Japanese Lesson Study in an Initial Teacher Education Program: Benefits and Challenges. *Canadian Journal of Education,* 32 (4), 734-763.

Chokshi, S., & Fernandez, C. (2004). Challenges to importing Japanese lesson study: Concerns, misconceptions, and nuances. *Phi Delta Kappan,* 85 (7), 520-525.

Chokshi, S., & Fernandez, C. (2005). Reaping the systemic benefits of lesson study: Insights from the U.S. *Phi Delta Kappan,* 85 (7), 674-680.

Cimer, S. O., & Cimer, A. (2012). Issues around incorporating reflection in teacher education in Turkey. *Journal of Turkish Science Education*, 9 (1), 17-30.

Coe, K. (2010). *The process of lesson study as a strategy for the development of teaching in primary schools: A case study in the Western Cape Province, South Africa. Unpublished PhD Dissertation.* Stellenbosch: Stellenbosch University.

Coe, K., Carl, A., & Frick, L. (2010). Lesson study in continuing professional teacher development: A South African case study. *Acta Academica,* 42 (4), 206-230.

Cohen, L., Manion, L., & Morrison, K. (2011). Research methods in education (7th ed.). Routledge, London.

Earley, P., & Bubb, S. (2004). *Leading and managing continuing professional development: Developing people, developing schools.* London: Paul Chapman Publishing.

Elo, S., & Kyngas, H. (2008). The qualitative content analysis process. *Journal of Advanced Nursing,* 62(1), 107–115.

Feiman-Nemser, S. (2001). From preparation to practice: Designing a continuum to strengthen and sustain teaching. *Teachers College Record*, 3 (6), 1013-1055.

Fernandez, C. (2002). Learning from Japanese approaches to professional development: The case of lesson study. *Journal of Teacher Education,* 53 (5), 393-405.

Fernandez, C., & Chokshi, S. (2002). A practical guide to translating lesson study for a U.S. setting. *The Phi Delta Kappan*, 84 (2), 128-134.

Fernandez, C., Cannon, J., & Chokshi, S. (2003). A US–Japan lesson study collaboration reveals critical lenses for examining practice. *Teaching and Teacher Education,* 19, 171-185.

Fernandez, M. L. (2005). Learning through microteaching lesson study in teacher preparation. *Action in Teacher Education*, 26 (4), 37-47.

Fullan, M. (2007). *The new meaning of educational change* (4th ed.). New York: Teachers College Press.

Garet, M. S., Porte, A. C., Desimone, L., Birman, B. F., & Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal*, 38 (4), 915-945.

Ghebremuse, T. (2004). Survey of Eritrean education: Traditional and modern. *Eritrean Studies Review,* 4 (1), 131-154.

Guba, E. G. (1981). Criteria for assessing the trustworthiness of naturalistic inquiries. *Educational and Communication and Technology Journal,* 29 (2), 75-91.

Guskey, T. (1994). Results-oriented professional development: In search of an optimal mix of effective practices. *Journal of Staff Development,* 15 (4), 42-50.

Guskey, T. (2000). *Evaluating professional development.* Thousand Oaks, CA: Corwin Press.

Guskey, T., & Yoon, K. S. (2009). What works in professional development? *Phi Delta Kappan,* 90 (7), 495-500.

Henning, E., Van Rensburg, W., & Smit, B. (2004). *Finding your way in qualitative research* (1st ed.). Pretoria: Van Schaik Publishers.

Hiebert, J., Gallimore, R., & Stigler, J. W. (2002). A Knowledge base for the teaching profession: What would it look like and how can we get one? *Educational Researcher,* 31 (5), 3-15.

Joyce, B., & Showers, B. (2002). *Student achievement through staff development* (3rd ed.). Alexandria, VA: ASCD.

Kennedy, A. (2005). Models of continuing professional development: A framework for analysis. *Journal of In-service Education,* 31 (2), 235 -250.

Kennedy, M (2016). How Does Professional Development Improve Teaching? *Review of Educational Research*, 86 (4), 945-980.

Lewis, C. (2002a). Does lesson study have a future in the United States? *Nagoya Journal of Education and Human Development*, 1 (1), 1-23.

Lewis, C. (2002b). *Lesson study: A handbook of teacher-led instructional change.* Philadelphia: Research for Better Schools.

Lewis, C., & Tsuchida, I. (1998). A lesson is like a swiftly flowing river: How research lessons improve Japanese education. *American Educator*, 22 (4), 14-17, 50-52.

Lewis, C., Perry, R. R., & Hurd, J. (2009). Improving mathematics instruction through lesson study: A theoretical model and North American case. *Journal of Mathematics Teacher Education*, 12, 285-304.

Lieberman, A. (1995). Practices that support teacher development: Transforming conceptions of professional learning. *Phi Delta Kappan,* 76 (8), 591-596.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Beverly Hills, CA: Sage.

Little, J. W. (1993). Teachers' professional development in a climate of educational reform. *Educational Evaluation and Policy Analysis,* 15 (2), 129-151.

Lortie, D. C. (1975). *School teacher: A sociological study*. Chicago: The University of Chicago Press.

Loucks-Horsley, S., Stiles, K. E., Mundry, S., Love, N., & Hewson, P. W. (2010). *Designing professional development for teachers of science and mathematics* (3rd ed.). Thousand Oaks, CA: Corwin, A Sage Company.

Matthews, M. E., Hlas, C. S., & Finken, T. M. (2009). Using lesson study and four-column lesson planning with preservice teachers. *Mathematics Teacher,* 102 (7), 504-508.

Merriam, S. B. (1998). *Qualitative research and case study application in education* (2nd ed.). San Francisco: Jossey-Bass.

Mertens, D. M. (1998). *Research methods in education and psychology: Integrating diversity with quantitative and qualitative approaches.* Thousand Oaks: Sage Publications.

Minstry of Education (2009). *Eritrea: Essential education indicators 2008/09.* Asmara: Ministry of Education.

Murata, A. (2011). Introduction: Conceptual overview of lesson study. In L. C. Hart, A. Alston, & A. Murata (Eds.), *Lesson study research and practice in mathematics education: Learning together* (pp. 1-12). London: Springer.

Neuman, L. W. (2011). *Social research methods: Qualitative and quantitative approaches* (7th ed.). Boston: Pearson.

Pankhurst, R. (1972). Education in Ethiopia during the Italian fascist occupation (1936-1941). *The International Journal of African Historical Studies,* 5 (3), 361-396.

Patton, M. Q. (2002). *Qualitative research and evaluation methods* (3rd ed.). Thousand Oaks, CA: Sage Publications.

Posthuma, B. (2012). *Mathematics teachers' reflective practice within the context of adapted lesson study. Pythagoras*, 33(3), 1-9.

Puchner, L. D., & Taylor, A. R. (2006). Lesson study, collaboration and teacher efficacy: Stories from two school-based math lesson study groups. *Teaching and Teacher Education,* 22 (7), 922–934.

Reddy, C. (2004). Democracy and in-service processes for teachers: A debate about professional teacher development programmes. In Y. Waghid, & L. Le Grange (Eds.), *Imaginaries on democratic education and change* (pp. 137-146). Pretoria: South African Association for Research and Development in Higher Education.

Rock, T. C., & Wilson, C. (2005). Improving teaching through lesson study. *Teacher Education Quarterly,* 32 (1), 77-92.

Sengul, S.H., Cetin, G. & Gur, H. (2008). The primary school science teachers' problems in science teaching. *Journal of Turkish Science Education,* 5 (3), 82-88.

Sparks, D. (2002). *Designing powerful professional program for teachers and principals.* Oxford, OH: National Staff Development Council.

Stake, R. E. (1995). *The art of case study research.* Thousand Oaks, CA: Sage Publications.

Stepanek, J., Appel, G., Leong, M., Mangan, M., & Mitchell, M. (2007). *Leading lesson study: A practical guide for teachers and facilitators.* Thousand Oaks, CA: Corwin Press.

Stigler, J. M., & Hiebert, J. (1999). *The teaching gap: Best ideas from the world's teachers for improving education in the classroom.* New York: Free press.

Strauss, A. (1987). *Qualitative analysis for social scientists.* Cambridge: Cambridge University Press.

Strauss, A., & Corbin, J. (1990). *Basics of qualitative research: Grounded theory procedures and techniques.* Newbury Park CA: Sage.

Taylor, A. R., Anderson, S., Meyer, K., Wagner, M. K., & West, C. (2005). Lesson study: A professional development model for mathematics reform. *The Rural Educator*, 26 (2), 17-22.

Walker, R. (1980). The conduct of Educational case study: Ethics, theory and procedures. In W. B. Dockerell, & D. Hamilton (Eds.), *Rethinking educational research* (pp. 30-63). London: Hodder and Stoughton.

Watanabe, T. (2002). Learning from Japanese lesson study. *Educational Leadership*, 59 (6), 36-39.

Xu, H., & Pedder, D. (2015). Lesson study: An international review of the research. In P. Dudley (Ed.), *Lesson study: Professional learning for our time* (pp. 24-47). Abingdon: Routledge.

Yin, R. K. (1984). *Case study research: Design and methods* (Vol. 5). Beverly Hills: CA: Sage Publications, Inc.

TÜRK FEN EĞİTİMİ DERGİSİ
Yıl 15, Sayı 3, Eylül 2018

Journal of
TURKISH SCIENCE EDUCATION
Volume 15, Issue 3, 2018

http://www.tused.org

The Influence of Technological Pedagogical and Content Knowledge (TPACK) Approach on Science Literacy and Social Skills

Luthfia Irmita[1], Sri Atun[2]

[1] *Master Student at Chemistry Education, Graduate Programe, Universitas Negeri Yogyakarta*
[2] *Prof. Dr. at Departemen Chemistry education Faculty Mathematics and Natural Science, Universitas Negeri Yogyakarta, Jl. Colombo No. 1 Depok, Sleman, Yogyakarta, Indonesia, 55281, ORCID ID: 0000-0002-6225-4255*

Received: 06.02.2017 **Revised:** 03.07.2018 **Accepted:** 27.09.2018

The original language of article is English (v.15, n.3, September 2018, pp.27-40, doi: 10.12973/tused.10235a)

ABSTRACT

The purpose of this study was to determine the effects of Technological Pedagogical and Content Knowledge (TPACK) approach to scientific literacy and social skills of students. The research is a quasi-experiment design of pretest and posttest control group. The research population were all students at 11th grade of natural science classes consisting the 1st, 2nd, 3rd and 4th classes in SMAN 2 Banguntapan and the total were 118 students. The used samples were 1st and 2nd classes and had 62 students in total. The sampling technique is cluster random sampling with the 1st class of 11th grades of natural science as the control group and the 2nd class of 11th grade of natural science as the experimental group. The treatment given to the experimental group was the learning the rate of reaction by using the TPACK approach with *discovery learning* models, while that of the control group was learning rate of reaction by using *teacher-center* approach with direct instructional model. The data collection tolls were the test of science literacy, consisting social skill questionnaire and social skill observation sheet. The data analysis technique was MANOVA by using SPSS and Rasch models applying Ministep. The results showed that there were an influence of the TPACK approach to science literacy and social skills of students at the level of significance ($p=0.00<0.05$). The influence of the TPACK approach to science literacy (*sig.*= 0.00), and no influence of the TPACK approach to social skills of students of SMAN 2 Banguntapan with a significant value (*sig.*= 0.137).

Keywords: TPACK approach; science literacy; social skills; senior high school students.

INTRODUCTION

The curriculum released in 2013 formulated that learning process should be able to develop the attitudes, knowledge, and skills (Kemendikbud, 2013). It has purpose to prepare Indonesian to have the ability to live as individuals and citizen who are godly, productive, creative, innovative, and affective and give contribution to the society, nation, state, and world civilization. The process of learning chemistry should be implemented by many integrating aspects such as attitude, knowledge and skill (BSNP, 2006) to develop scientific literacy and social skills of students and achieved the goal of the 2013 Indonesian curriculum

Corresponding author e-mail: sriatun@uny.ac.id

© ISSN:1304-6020

and the national education. In process of learning chemistry or other scientific subjects, students are not only given limited factual knowledge, but they also need to be trained to explore and implement their ideas related to science (Knain, 2005).

Currently there are many schools that implement the teacher centered learning process in which students receive the information from teachers and teachers do not encourage students to gain knowledge by themselves. As a result, students tend to be passive and have less ability to work in team. In addition, students have less encouragement to solve problem that becomes the subject of learning, use scientific ability to scientifically explain the phenomena, and collect information and scientific evidence. Thus, student motivation and achievement stay low for scientific literacy.

The scientific literacy ability of Indonesia in 2006, 2009, and 2012 was ranked 50th of 57 participating countries, 60th of 65 participating countries, and 64th of 65 participating countries respectively (OECD, 2013). Lau (2014) explained that scientific knowledge of East Asian students stays low, but their interest and desire are high to learn. It is caused through implementing the traditional teaching method, little activity and interaction in the class and the lack of emphasis on the application of science or knowledge. Since the learning activities have not fully involved students in the process of acquiring knowledge, the science literacy of students is low. It is possible to overcome this by applying a learning that can make students actively involved in the process of discovery knowledge and can drill students in solving problems presented in the form of animation, simulation, or video.

One of the methods to improve scientific literacy skill is to adopt TPACK approach in the learning process. TPACK approach is a learning approach that combines content, pedagogy, and technology (So & Kim, 2009; Bozkurt, 2014; Khan, 2011; Park, Jang, & Chen, 2011). Li (2012) also said that TPACK is an approach depends on a principle as “learning is the basis to broaden knowledge, understand scientific investigation, implement effective teaching methods for science”. TPACK approach can be integrated with the model that can train students to independently gain new knowledge, even it still gives teachers occasion to provide guidance. One of models that can be used is discovery learning model. In this model, teachers do not present the teaching material in the final form, but students are encouraged to acquire their knowledge and construct it to gather new knowledge (Shah, 2004; Klauge 2011; Suminar & Meilani, 2016; Balim, 2009). TPACK approach when combined with the discovery learning model, encourages students to solve problems that become learning topics, using their scientific ability to scientifically explain the phenomenon, and to collect information and scientific evidence for problem solving. Thus, students must be trained for scientific literacy.

TPACK approach with discovery learning models encourages students to solve problem which is the subject of learning by integrating technology, pedagogy, and content knowledge. The chemistry curriculum designed to plan and implement learning activities using technology as a pedagogical goal to be very effective in student learning process (Pekdag, 2010). Learning by using TPACK approach rely on scientific literacy, which is the ability to explain scientific phenomena and collect information as well as scientific evidence to scientifically solve the problem and increase the social skills. In discovery learning students are required to perform various activities to collect information, compare, categorize, analyze, integrate, reorganize the material and make conclusions. The learning stages of discovery learning model are stimulation, problem identification, data collection, data processing, verification, and generalization (Suminar & Meilani, 2016; Kemdikbud, 2013; Syah, 2010:243).

Scientific literacy is the ability to apply science to identify questions and draw conclusions based on scientific evidence (Ardianto & Rubini, 2016; Bybee, 2008; Holbrook & Rannikmae 2007; Murcia, 2009; Schroeder, Mckeough, Graham, Stock, & Bisanz , 2009).

The scientific literacy is the ability to master scientific content (knowledge), scientific process (competencies), scientific context, and attitude (Bybee, 2008; OECD, 2006; OECD, 2013). The scientific literacy and technology learning are previously constructed on constructivist learning principles (Park & Oliver, 2008). The high scientific literacy will be followed by increasing social skills. The scientific literacy is closely related to the social abilities of students including the understanding of science, development of intellectual skill and communication, development of character and positive attitude, achievement of the objectives in socio scientific education, and the ability to scientifically make decisions(Holbrook & Rannikmae, 2007). The scientific literacy refers to ability of a person to comprehend and apply the knowledge of chemistry in everyday life in terms of understanding of three major aspects of knowledge, awareness, and the application of chemistry in daily life appropriately and effectively (Thummathong & Thathong (2016). In his research, Roth (2007) said that the scientific literacy relates with skill in communicating with others. Students are required to be able to apply science in daily life to benefit in their own life. Social skills can be learned in the chemistry. The social skills are shown as good cooperation, enthusiasm for completing the task, good communication skill in group discussion and the respect for opinions of others (Combs & Slaby, 1977).

Learning through using TPACK approach with discovery learning model invites students to actively discuss among students to construct knowledge, carry out experiment, and answer the questions contained in the student worksheet. So, students have many opportunities to express opinions, ask questions, and respond to the opinions of others. Literacy of science and social skills can be trained by using the discovery learning model and the TPACK approach. The social skills that are expected to arise during the rate of reaction to learning through using TPACK approach with discovery learning model that is in the form of ability to work together, mutual respect, and skills to communicate. The ability to work together, mutual respect, and skills to communicate can be developed during the learning process.

The one of chemistry learning materials in the 11^{th} grade is the rate of reaction. In the rate of reaction learning, there are many opportunities for students to be stimulated to observe the chemical phenomenon, watch animation or video of the rate of reaction, the factors affecting the rate of reaction, experiment on the factors that affect the rate of reaction, and apply the concept of rate of reaction in daily life. The learning process for the rate of reaction has not yet been used through the approach and the appropriate learning model. So, the effects on science literacy and social skills have not been researched for TPACK approach and discovery learning models. This study aims to uncover the effect of TPACK approach with discovery learning model to scientific literacy and social skills of students of SMAN 2 Banguntapan., The following research questions are tried to be answered according to the aim of the study. The following research questions is: “Does the TPACK approach with discovery learning models affect the scientific literacy and social skills students?

METHODS

1. Reseach Design

The type of the research was quasi experiment. The quasi experimental methods that involve the creation of a comparison group are most often used when it is not possible to randomize individuals or groups in treatment and control groups. The research design was required to apply pretest-posttest control group (Sugiyono, 2012). In the experimental group, students were treated with TPACK approach application with discovery learning model while in the control group was given treatment of teacher centered learning with direct instructional model.

2. Participants

The research was conducted at SMAN 2 Banguntapan, Yogyakarta on October 4 to 24, 2016. The participants in this study were all of 11th grade students from the natural science classes in SMAN 2 Banguntapan and the total were 118 students. The used samples were the 1st and the 2nd class in total 62 students. The sampling technique is random sampling with the 1st class of 11th grade of natural science as the control class and the 2nd class of 11th grade of natural science as the experimental class.

3. Research Procedure

The steps taken in this study were listed in below.

Pre-study

a. To ask for permission to Head of SMAN 2 Banguntapan to conduct research.
b. To conduct an observation in the school where the research proceeded to collect information about student data, student characteristics, schedule, and suggestions that exist in schools and can be used to support the implementation of the research.

Research Preparation

The procedure of research implementation consists of two stages.

a. Determine population and sample of the research.
b. The preparatory phase: the researcher prepares the basic competencies indicator analysis, syllabus, course plans, a grid of pretest and posttest and student worksheet, skill observation sheets, social and observational sheets of the effectiveness of learning using discovery learning model and TPACK approach.

Implementation of Research

The implementation phase of the research was included three main stages.

a. Perform pretest with the same questions in the experimental group and control group.
b. Perform learning appropriate activities on the rate of reaction material with the learning set in each group, apply learning through using discovery learning model with the TPACK approach in the experimental and learning groups teacher centered conventional approach applied in control group.
c. Posttest with the same questions in the experimental class and control classes;

Analysis and Reporting of Results

a. Perform tabulation and data analysis.
b. Discussion and conclusion.

4. Instrument of Collecting Data

The instrument of this study consists of learning devices and three data-collection instruments. The learning tool is the course plan and student worksheet for the experimental group that is prepared using the discovery learning model and TPACK approach based on basic competencies in curriculum 2013. Lesson plan and student activity sheet for control group which is constructed by using direct instruction model and teacher centered approach based on basic competencies in curriculum 2013. The data collection instruments are the student science literacy test, social skill observation sheet and the questionnaire of social skills. The science literacy test consists of 8 descriptive questions with science literacy indicators compiled based on indicators of science content capabilities, science processes, and the scientific context. Student social skills observation sheets use indicators of cooperation, mutual respect. and communication skills with 3 criteria attached in the assessment rubric. Student social skills questionnaire consists of 20 statements both positive and negative. The questionnaire filled by students with three criteria, often, rarely, and never.

5. Data Analysis

The data were collected from the results of pretest and posttest of science literacy and social skills. The increase in pretest and posttest results of students was analyzed using a gain score. The data analysis techniques in this study were a multivariate analysis with MANOVA technique at significance level of 0.05 and Rasch model analysis by applying Ministep.

Analysis through using SPSS was used to answer hypotheses, while the Rasch analysis was used to determine the science literacy indicators which most affected TPACK approach, the ability level of students, and the level of difficulty of test. Before multivariate analysis of variance (MANOVA) was done through using SPSS, the assumption must be met consisting of normality and homogeneity of pretest and posttest data and the correlation between the dependent variables.

FINDINGS

1. Improvement of Science Literacy and Social Skills

Data of science literacy and social skills from control and experimental group included pretest and posttest data. The increased science literacy and social skills of students was shown in gain value from each group and can be seen on the Figure 1.

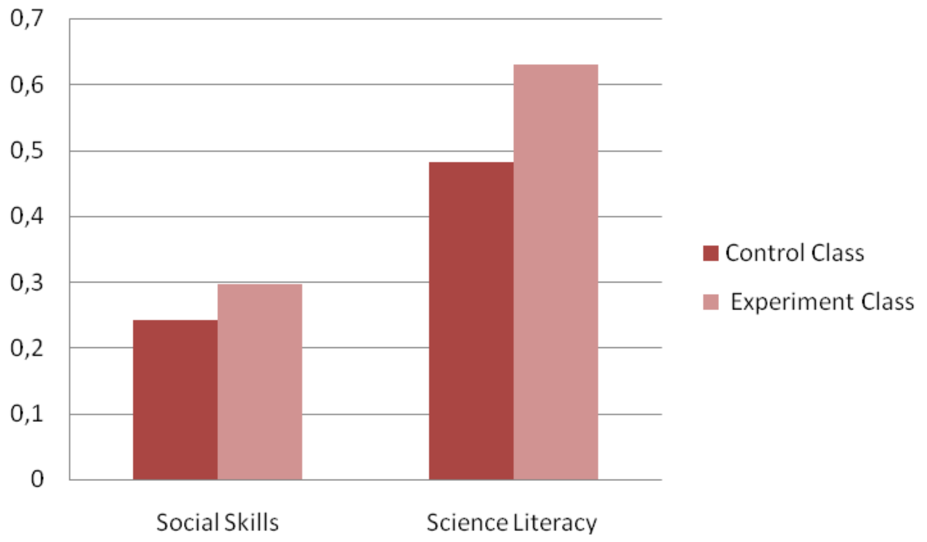


Figure 1. Improvement of The Gain Value of Science Literacy and Social Skills

2. Normality, Homogeneity and Correlation Test

The results showed the initial and final conditions of each studied variable. Normality test of science literacy and social skills was analyzed through *Kolmogorov-Smirnov* test with SPSS 16.0. and the results are shown on the Table 1.

Table 1. Results of Normality Test

No	Result	Variable	**Significance Value**	
			Control	Experiment
1	Pretest	SL	0,200	0,185
		SS	0,146	0,175
2	Posttest	SL	0,200	0,200
		SS	0,200	0,200

The significance value of normality test of science literacy and social skills was over than α (0.05). So, H_0 was accepted. This meant that the data of science literacy and social skills of control and experimental groups were distributed normally. From homogeneity test of science literacy and social skills of students, the data showed significance value by 0.246 which is bigger than the α value (0.05). So, H_0 was accepted. This meant that the data science literacy and social skills had homogeneous variances. Before hypothesis test, correlation test of dependent variable consisting of science literacy and social skills was conducted to imply the correlation between two variables. Correlation test results are shown on the Table 2. The *Pearson correlation* and significance values were 0.341 and 0.007 respectively. The significance value was less than the α value (0.05). It meant that there was a significant correlation between science literacy and social skills.

Table 2. Results of Correlation Test

No			Science Literacy	Social Skills
		Pearson Correlation	1	0,341
1	Science Literacy	Sig. (2-tailed)	-	0,007
		N	62	62
		Pearson Correlation	0,341	1
2	Social Skills	Sig. (2-tailed)	0,007	-
		N	62	62

3. Influence of TPACK Approach to Science Literacy and Social Skills

Hypothesis test was done by using MANOVA. After correlation test had been fulfilled, MANOVA test was administered. The results of hypothesis test were shown in the significance value of *Hotteling's Trace* as 0.000. Hypothesis test results showed that significant value was less than the value of α (0.05). It meant that H_0 was rejected. It can be concluded that there was a significant effect on implementation of TPACK approach to science literacy and social skills of students at 11th grade of natural science classes in SMAN 2 Banguntapan at the significance 0.05. The MANOVA test results were presented on Table 3.

Table 3. Results of MANOVA Test

Effect		**Value**	**F**	**Hypothesis df**	**Error df**	**Sig**
Intercept	Pillai's Trace	.944	5.020E2[a]	2.000	59.000	.000
	Wilks' Lambda	.056	5.020E2[a]	2.000	59.000	.000
	Hotelling's Trace	17.016	5.020E2[a]	2.000	59.000	.000
	Roy's Largest Root	17.016	5.020E2[a]	2.000	59.000	.000
Approach	Pillai's Trace	.229	8.751[a]	2.000	59.000	.000
	Wilks' Lambda	.771	8.751[a]	2.000	59.000	.000
	Hotelling's Trace	.297	8.751[a]	2.000	59.000	.000
	Roy's Largest Root	.297	8.751[a]	2.000	59.000	.000

a. statistical Exact
b. Design: intercept +approach

4. Partial Test of TPACK Approach to Science Literacy and Social Skills

The test of MANOVA showed not only all the test results but also the result of the partial test. The value of partial test showed a significance value for science literacy (*sig.*=0.00) that was less than the α value. It can be concluded that the TPACK approach effected science literacy of students. On the other hand, the significance value of social skills (*sig.*=0.137) was bigger than the α value. It can be concluded that the TPACK approach had no influence on the social skills of students. Test results are presented on Table 4.

Table 4. Results of MANOVA Partial Test

Source	**Dependent**	**Type III Sum of**	**df**	**Mean**	**F**	**Sig.**

		Squares		Square		
Corrected Model	Science Literacy	.343[a]	1	.343	17.708	.000
	Social Skills	.049[a]	1	.049	2.276	.137
Intercept	Science Literacy	19.157	1	19.157	989.942	.000
	Social Skills	4.486	1	4.486	208.912	.000
Approach	Science Literacy	.343	1	.343	17.708	.000
	Social Skills	.049	1	.049	2.276	.137
Error	Science Literacy	1.161	60	.019		
	Social Skills	1.288	60	.021		
Total	Science Literacy	20.846	62			
	Social Skills	5.858	62			
Corrected Total	Science Literacy	1.504	61			
	Social Skills	1.337	61			

a. R Squared = .228 (Adjusted R Squared = .215)

b. R Squared = .037 (Adjusted R Squared = .020)

5. The Most Influential Indicators of Science Literacy toward TPACK approach

Analysis result through using Rasch model with Ministep showed that the most influential indicator of science literacy toward TPACK approach applied in discovery learning model was scientific proses indicator. The results of the analysis can be seen from the variable map on Figure 2. Based on a variable map, information can be found about students' abilities and the level of difficulty of the test. The abilities of the students were shown on the left side while the difficulty level was shown on the right side.

Based on the variable map, the abilities of students in experimental group distributed equally. At the most difficult question, the students who had code P01 and P04 could solve the problem. In addition, all students could complete the easiest questions, so it shows that there was no student who needed special treatment in learning. It can be seen from the variable map that question on E1, E4, and E13 were the easiest problems for students of experimental group, then majority of students could answer them correctly. The questions on E1, E4, and E13 represented indicator of science literacy which was one of the aspects of the scientific process. Then in that case, the material for rate of reaction was the most influential indicator toward TPACK approach.

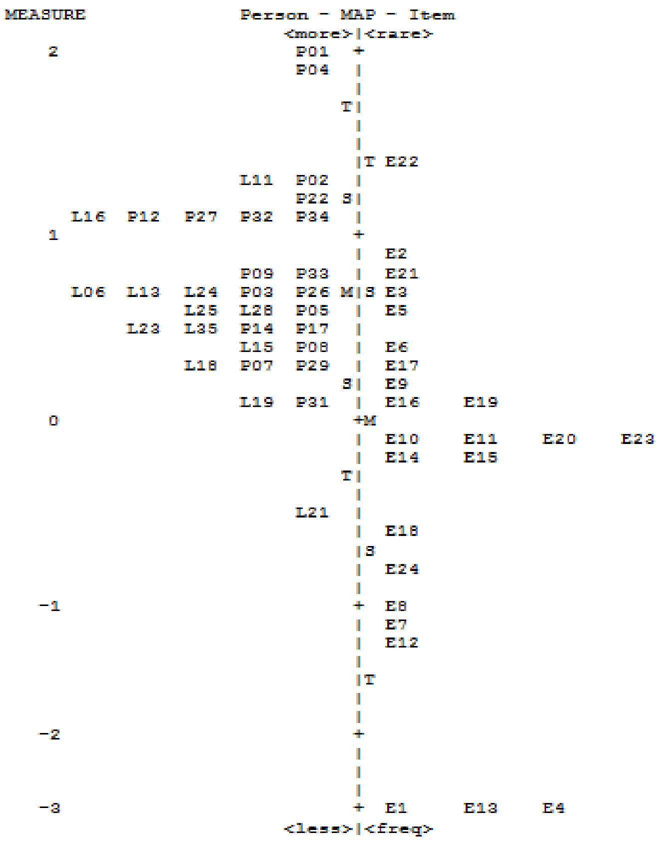


Figure 2. *Variable Map* of Science Literacy of Students

DISCUSSION and CONCLUSION

The implementation of the learning process was done four times for in the control group and experimental group. The learning process in the control group was held based on course planand student worksheets that were arranged to use teacher centered learning and followed rules in basic competencies based on curriculum-13, while experiment in the experimental group was conducted with course plan and student worksheet application designed through TPACK approaches and discovery-learning model based on curriculum-13. Before the rate of reaction material was delivered in the class, control and experimental group were given quiz about science literacy and questionnaire about social skills. And at the end of class, they were given final quiz. During the learning process, two observers observed the social skills of students and the all activities in the classes were documented via video recording.

The effect of TPACK approach to science literacy and social skills can be seen from the results of MANOVA test. the typical assumption of normality, homogeneity, and correlation had to be met before conducting MANOVA. Normality test results for pretest and posttest data showed normal distribution. Homogeneity test results indicated that the data had homogeneous variances. Correlation test results showed that science literacy significantly correlated with social skills. In accordance with the opinion of Holbrook & Rannikmae (2007) science literacy is closely related to social skills of students including the understanding of science, development of intellectual skill and communication, development of character and positive attitude, achievement of the objectives in socio-scientific education, and the ability to scientifically make decisions.

MANOVA test results indicated that significance value is smaller than the value of α.

So, it can be concluded that TPACK approach affected science literacy and social skills of students of SMAN 2 Banguntapan at the 0.05 significance level. The TPACK approach is one approach that focuses on technology, pedagogy, and materials (So & Kim, 2009; Ndongfack, 2015; Koehler & Mishra, 2009). The TPACK approach applied in the discovery learning model is learning process with discovery learning step combined with the technology in the form of animations, simulations, and virtual labs as learning media and resources. Khan (2011) said that learning involving pedagogy and knowledge content by using technology can improve conceptual understanding of students. This is also consistent with the results of the studies of Mineo, Fazio and Tarantino (2005); Drechsler and Driel (2008); Cavanaugh and Dawson (2010); Qablan, Abuloum and Al-Ruz (2009). The research of Sinaga, Kaniawati and Setiawan (2017) showed that scientific literacy increases with learning using text book related to daily life. In learning through using TPACK approach, students can increase science literacy and be accompanied by improvement of social skills of students. The result of research by Tukiran, Suyatno and Hidayati (2017) showed that the learning process used teaching materials developed from natural product chemistry (NPC) If effectively implemented to students to improve life skills, academic skills, and social skills. At the stage of stimulation, students were asked to observe phenomena, animations, or video-related the rate of reaction. Through this stage science literacy of students can evolve for example on indicators identifying phenomena/problems for subsequent investigation where students can find the key words of the problem for scientific investigation. In addition, the social skills of students can also develop for example listening to explanations of other peoples and not interrupt conversations of other people. In addition to the increasingly growing science literacy of students, social skills of students can also flourish. This is in line with the research results by Setiawati and Senam (2015) that states the development of science literacy of students are also accompanied by the development of student attitudes such as actively asking questions about IPA issues, actively answering questions about IPA issues, actively responding to friend opinions about IPA issues, with enthusiasm, honest in taking observation data, and responsible in the implementation of practicum activities.

The TPACK approach applied in the discovery learning model is constructivism learning model and contextual approach. Learning of scientific literacy and technology is the learning process built by the constructivism principles in which comprehension of students depends on their thinking process when they get involved with learning experience and it is associated with their previous understanding concept (Park & Oliver, 2008). The purpose of implementation of TPACK learning framework is to enable students to do simulations interactively by applying learning media-based animation to comprehend the concept and solve the daily problem. The TPACK approach relating in discovery learning model is learning materials combined with the technology such as animation programs, simulations, and virtual labs as media and learning resources. Darmawan (2016) said that constructivism-based learning with TPACK approach is a learning that involves the nature of knowledge needed to integrate technology in learning. The Learning with TPACK framework is implemented so that students familiarize themselves in conducting simulations in an interactive way using animation learning media directly to understand the concept and solve a problem that occurs in daily life.

The learning in the experimental group was conducted in laboratory. Integrated learning theory with more practice made students to construct comprehension well. Students were stimulated to find, try, and build their concept during learning process. After they found the sought concept, they would discuss and get explanation from teacher to develop their understanding. This was supported by the results of research by Bozkurt (2014) which explains TPACK as significantly affected the improvement of academic value for students of teaching physics. Practical learning and discussion allow students to interact with each other and transfer knowledge. This was supported through results of research by Matthewe (2004) that the stimulant of working in team induced students to do social actions such as respect of their friends and it gave equal comprehension among students. In addition, students could collaborate more actively.

For the rate of reaction material in the experimental group, learning was done with syntax repetition of discovery learning model by TPACK approach seven times. At the first meeting, the learning proses spent time longer because students stayed unfamiliar to TPACK approach and discovery learning model. As a result, students needed more time to identify the problem based on practiced phenomenon. It was concluded by analyzing their worksheets/LKS and there were just 32% of students who answered the problems in worksheet at the stage of problem identification.

After the second meeting, the students started to adapt to follow the learning syntax because the longer the students used to follow the learning through using TPACK approach with discovery learning model. This is evidenced by the observation of the implementation of learning that reaches 100%. Consequently, they could identify the problem, explain the phenomena based on the concept of the rate of reaction, collect information, and scientific evidence to solve problem in daily life. The students longer adapted to follow the learning process by using TPACK approach applied in discovery learning models. It was detected by 98% of students answer to the questions on the worksheet correctly at the fourth meeting. Furthermore, the questionnaire about student interest showed that students tended to be active, enthusiastic, and amused during the learning rate of reaction by applying TPACK approach. It can be seen on the Figure 3.

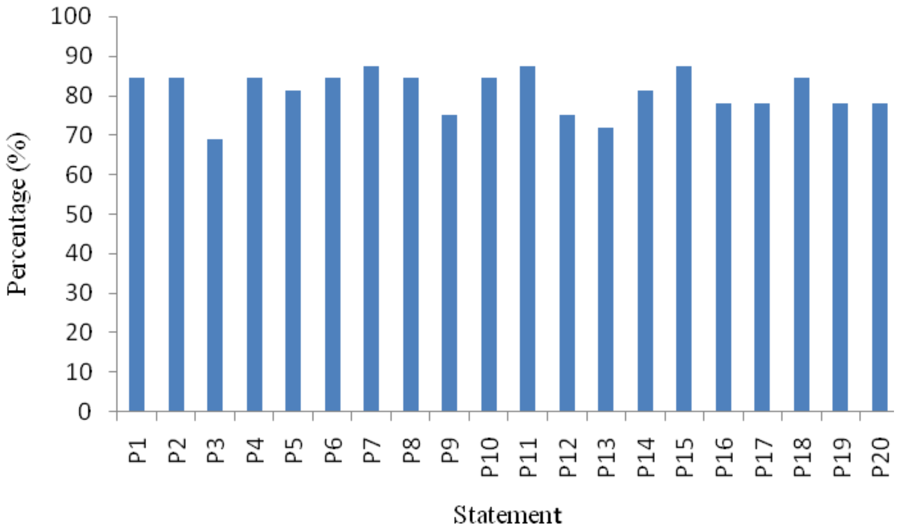


Figure 3. Graph Interests Against Student Learning

The questionnaire about student interest averagely showed 87% of students was more active, happy, and enthusiastic during the learning of the rate of reaction by using TPACK approach that involves the examples of chemical phenomena in daily life. Li (2012) said that the TPACK is an approach having principle that learning process is the basis to develop knowledge, understand scientific investigation which makes it the appropriate teaching method for science. The results of data analysis from student worksheet, in the data processing stage showed that students can explain the scientific phenomenon that occurs in everyday life and associated with the concept of rate of reaction, can explain phenomena associated with factors that affect the rate of reactions in everyday life with the theory of collision. Student ability to connect the concept of rate of reaction with daily life phenomenon will make it easier for students to solve problems. This is in accordance with the results of the study by Carvalho, et al. (2015). This descriptive and interpretive study aims to better understand how to mobilize effective feedback in science classes by applying activities based on real life problems which intended to promote critical thinking. Science literacy is important to enable children in the principles of lifelong learning and motivates them to learn everything and apply it in daily life. In accordance with the study of Chen (2011), it said that the learning involving science literacy is effective to improve student understanding of the concept and easier to remember information and apply it. In other words, students can improve not only science literacy but also social skills by applying the method. This had something in common with the study of Setiawati and Senam (2015) which stated that the development of science literacy of students was also accompanied by the development of student attitude such as being active to ask and answer questions about the issue of natural science, active to respond opinion of friends on the about issue of natural science, active during practicum, honest to collect the observational data and responsible to do the tasks during the practicum.

In the control group, the learning for the rate of reaction took place with the teacher centered approach. The learning was done with the teacher explanation and the students take note and record the teacher explanation. This is the reason for lack of development in student science literacy in the control group. The improvement of science literacy of control and experiment group students are much different. The teachers provide opportunities for the students to discuss answers to questions presented by the teachers. In addition, the students are also grouped to conduct practicum activities and discuss questions answered by the teachers. Generally, the TPACK approach applied in discovery learning model affected science literacy and social skills. However, the partial test results of MANOVA showed that the treatment did not give effect for social skills. Although implementation of the TPACK approach improved the science literacy of student, it did not affect their social skills. The data on Figure 1 showed the improvement of social skills

experimental group did not have significant difference with control group. It was caused by same activities given both classes during learning process such as doing discussion and practicum.

The results of the Rasch analysis showed that the most influential science literacy indicator toward the TPACK approach was process aspect of science literacy. Indicators of science literacy were content, process, and context of science (OECD, 2013). The indicators of science process included identifying scientific questions, identifying problems of the phenomenon about the rate of reaction and the factors affecting the rate of reaction, describing or interpreting phenomena about the rate of reaction, explaining the phenomena associated with factors affecting the rate of reaction using the collision theory, seeking additional information to corroborate initial understanding about the factors affecting the rate of reaction, proving the correlation between phenomenon factors affecting the rate of reaction with the collision theory, applying the theory of rate of reaction to explain the phenomenon of that in daily life, and using scientific evidences to draw conclusions. The research of Sinaga, Kaniawati and Setiawan (2017) showed that scientific literacy increases with learning using text book related to daily life.

During the learning through TPACK approach applied in discovery learning model, students were demanded to construct their understanding, so they could adapt to identify the problem with a scientific phenomenon or news, explain and solve the daily life problem or phenomena associated with the rate of reaction. Consequently, their literacy could be developed in this aspect of the process. Arends (1997: 43) supported this condition with the statement that learning focusing on activities including identifying problems and discussing in groups can develop student skill to thoughtfully think and socialize. The TPACK approach with discovery learning models had significant impact on the science literacy and skill of students in SMAN 2 Banguntapan. Partially the TPACK approach affected science literacy but had no effect on social skills. Science literacy can be seen as the indicator of TPACK approach for the TPACK aspects of the science process because the questions that represent indicators on aspects of the science process can be answered by the most students.

Suggestions

The high achievement of science literacy of students was induced by their ability to construct and connect their knowledge with the application in daily life. The opinion of Holbrook & Rannikmae (2007) expressed the same condition that science would be easy to learn when it was related with the phenomenon in human life. In experiment group, student had stimulated to observe the chemical phenomena, analyze the concept of rate of reaction in daily activity, design and conducted the experiment on the rate of reaction factor, and apply the concept of rate of reaction in daily life. So, learning process for the rate of reaction by using the TPACK approaches with discovery learning model can develop not only science literacy but also the social skills such as the ability to work in team, respect each other, and communicate. Future studies with the TPACK approach with discovery learning model can be applied to other science subjects.

REFERENCES

Ardianto, D. & Rubini, B. (2016). Literasi sains dan aktivitas siswa pada pembelajaran IPA terpadu tipe shared. *Unnes Science Education Journal*, 5(1), 1153-1159.

Arends, R. (1997). *Classroom Instructional and Management.* New York: McGraw Hill Companies.

Balim, A. G. (2009). The effect of discovery learning on students’ success and inquiry learning skills. *Eurasian Journal of Educational Research*, 35, 1-20.

Bozkurt, E. (2014). TPACK levels of physics and science teacher candidates: problem and possible solutions. *Asia-Pacific Forum on Science Learning and Teaching*, 15(2), 1-22.

BSNP (2006). *Panduan Penyusunan Kurikulum Tingkat Satuan Pendidikan Jenjang Pendidikan Dasar dan Menengah.* Jakarta: BSNP.

Bybee, R. W. (2008). Scientific literacy, environmental issue, and pisa 2006: the 2008 paul f-brandwein lecture. *Journal of Science Education and Technology*, 17, 566-585.

Carvalho, C., Fiuza, E., Conboy, J., Fonseca, J., Santos, J., Gama, A. P. & Salema, M. H. (2015). Critical Thinking, Real Life Problems and Feedback in the Sciences Classroom. *Journal of Turkish Science Education*, 12(2), 21-31.

Cavanaugh, C. & Dawson, K. (2010). Design of online professional development in science content and pedagogy: a pilot study in Florida. *Journal of Science Education and Technology*, 19, 438-446.

Chen, L. C. (2011). The effects of integrated information literacy in science curriculum on first-grade student' memory and comprehension using the super3 model. *Knowledge Management & E-Learning: An International Journal*, 3(3), 399-411.

Combs, M. & Slaby, D. (1977). *Social Skills Training with Children.* New York: Plenum Press.

Darmawan, H. (2016). Pembelajaran berbasis konstruktivisme menggunakan media animasi dengan kerangka kerja TPACK dan gaya belajar terhadap prestasi belajar siswa. *Jurnal Formatif*, 6 (1), 1-11.

Drechsler, M. & Driel, J. V. (2008). Experienced teachers' pedagogical content knowledge of teaching acid-base chemistry. *Research in Science Education*, 38, 611-631.

Holbrook, J. & Rannikmae, M. (2007). The nature of science education for enhancing scientific literacy. *International Journal of Science Education*, 29(11), 1347-1362.

Kemendikbud. (2013). *Konsep Pendekatan Ilmiah.* Jakarta: Kemendikbud.
Khan, S. (2011). New pedagogies on teaching science with computer simulations. *Journal of Science Education and Technology*, 20, 215-232.
Klauge, A. (2011). Interaction design and science discovery learning in the future classroom. *Nordic Journal of Digital Literacy*, 6(3), 157-173.
Knain, E. (2005). Identity and genre literacy in high-school students' experimental reports. *International Journal of Science Education*, 27(5), 607-624.
Koehler, M. J. & Mishra, P. (2009). What is technological pedagogical content. *Contemporary Issues in Technology and Teacher Education*, 9(1), 60-70.
Lau, K. C. (2014). The science education of the East Asian regions-what we can learn from PISA. *Asia-Pacific Forum on Science Learning and Teaching*, 15(2), 1-18.
Li, Y. (2012). Pre-service science teacher in Xinjiang "scientific Inquiry"-pedagogical content knowledge research. *Asia-pacific Forum on Science Learning and Teaching*, 13(1), 12
Matthewe, B. (2004). Promoting emotional literacy, equity and interest in science lessons for 11-14 years old, the 'improving science and emotional development project. *International Journal of Science Education*, 26(3), 281-308.
Mineo, R. S., Fazio, C. & Tarantino, G. (2005). Pedagogical content knowledge development and pre-service physics teacher education: A case study. *Research in Science Education*, 36(3), 235-268.
Murcia, K. (2009). Re-thinking the development of scientific literacy through a rope metaphor. *Research in Science Education*, 39, 215-229.
Ndongfack, M. N. (2015). TPACK constructs: a sustainable pathway for teachers' professional development on technology adoption. *Creative Education*, 6, 1697-1709.
OECD. (2006). *Assessing Scientific, Reading and Mathematical Literacy A Framework for PISA 2006.* USA: OECD.
OECD. (2013). *Assessing Scientific, Reading and Mathematical Literacy: A Framework for PISA 2012.* USA: OECH Publishing.
Park, S. & Oliver, S. (2008). Revisiting the conceptualization of pedagogical content knowledge (PCK): PCK as a Conceptual tool to understand teachers as professionals. *Research in Science Education*, 38, 261-284.
Park, S., Jang, Y. & Chen, C. (2011). Is pedagogical content knowledge (PCK) necessary for reformed science teaching? *Research in Science Education*, 41, 245-260.
Pekdag, B. (2010). Alternative Methods in Learning Chemistry: Learning with Animation, Simulation, Video and Multimedia. *Journal of Turkish Science Education*, 7(2), 79-110.
Qablan, A. M., Abuloum, A. & Al-Ruz, J. A. (2009). Effective integration of ICT in Jordanian schools: an analysis of pedagogical and contextual impediments in the science classroom. *Journal of Science Education and Technology*, 18, 291-300.
Roth, W. (2007). Toward a dialectical notion and praxis of scientific literacy. *Journal Curriculum Studies*, 39(4), 377-398.
Schroeder, M., Mckeough, A., Graham, S., Stock, H. & Bisanz, G. (2009). The contribution of trade books to early science literacy: in and out of school. *Research in Science Education*, 39, 231-250.
Setiawati, I. & Senam. (2015). Pengembangan perangkat pembelajaran IPA berbasis SETS untuk meningkatkan scientific literacy dan foundational knowledge. *Jurnal Inovasi Pendidikan IPA*, 1(2), 178-190.
Sinaga, P., Karniawati, I. & Setiawan, A.(2017) Improving Secondary School Students' Scientific Literacy Ability Through The Design of Better Science Textbooks. *Journal of Turkish Science Education*, 14(4),92-107

So, H. & Kim, B. (2009). Learning about problem based learning: student teachers integrating technology, pedagogy and content knowledge. *Australasian Journal of Educational Technology*, 25(1), 101-116.

Sugiono. (2012) Metode Penelitian Pendidikan (Pendekatan Kuantitatif, Kualitatif dan R&D). Bandung: Alfabeta

Suminar, S. O. & Meilani, R. I. (2016). Pengaruh model pembelajaran discovery learning dan problem based lerning terhadap prestasi belajar peserta didik. *Jurnal Pendidikan Manajemen Perkantoran*, 1(1), 84-93.

Syah, M. (2004). *Psikologi Pendidikan Dengan Pendekatan Baru.* Bandung: PT. Remaja Rosda Karya.

Thummathong, R. & Thathong, K. (2016). Construction of a Chemical Literacy Test for Engineering Students. *Journal of Turkish Science Education*, 13(3), 185-198.

Tukiran, S. & Hidayati, N. (2017). Developing Teaching Materials of Natural Product Chemistry to Increase Student's Life Skills. *Journal of Turkish Science Education,* 14(2), 27-41.

TÜRK FEN EĞİTİMİ DERGİSİ
Yıl 15, Sayı 3, Eylül 2018

Journal of
TURKISH SCIENCE EDUCATION
Volume 15, Issue 3, September 2018

http://www.tused.org

Contribution toward Practical Design to Improve the Planning, Implementation, and Assessment of the Instruction of Chemistry Teachers

Jimmi COPRIADY[1], R. Usman RERY [2], Hutkemri ZULNAIDI [3], Masnaini ALIMIN [4]

[1] Prof. Dr., Chemistry Education Program, Faculty of Teacher Training and Education, University of Riau, INDONESIA, ORCID ID: 0000-0002-8457-2019
[2] Dr. Chemistry Education Program, Faculty of Teacher Training and Education, University of Riau, INDONESIA
[3] Dr. Department of Mathematics and Science Education, Faculty of Education, University of Malaya, MALAYSIA
[4] M.Ed. Chemistry Education Program, Faculty of Teacher Training and Education, University of Riau, INDONESIA

Received: 20.02.2017 **Revised:** 10.11.2017 **Accepted:** 19.07.2018

The original language of article is English (v.15, n.3, September 2018, pp.41-50, doi: 10.12973/tused.10236a)

ABSTRACT

This study aims to identify the contributions of teacher competency on teaching and learning for the subject of chemistry for the practical design, planning, and implementation to assessment of practical exercises in the science laboratory. The study used survey method with a five-point Likert scale questionnaire. The questions focused on designing, planning, implementing, and assessing practical sessions to discover teacher competency in the four listed aspects. Sample consisted of 236 chemistry teachers chosen at random from Riau, Indonesia. Structural Equation Model (SEM) was used to identify the teacher contribution of' practical design, planning, and implementation to assessment of practical exercise. Findings showed that the practical design, planning, implementation of teachers were contributed to assessment of practical exercise. Implementation seemed to be the best predictor contribution to assessment. Based on the findings, a strategic and united effort is necessary to increase the competency of teachers and to develop the latest practical materials.

Keywords: design competency, planning, implementation, practical assessment, chemistry

INTRODUCTION

The role and function of teachers as professionals are to perform the national education system and to cultivate the objectives of national education to develop student potential (British Council Teachers' Federation & CUPE British Council, 2009) in becoming knowledgeable (Chochran, 2006), efficient, creative, and independent (Widyatiningtyas, 2004) people. Teachers create experience in the learning session with students (Sexton, 2015). For this reason, the competency and professional development of teachers should be at par with how they conduct their learning (Avalos, 2011), play their role and function as

Corresponding author e-mail: jimmi.c@lecturer.unri.ac.id

© ISSN:1304-6020

knowledgeable and skilled teachers in teaching and learning. The Ministry of Education and Culture (2009) explained that the competency of chemistry teachers in teaching and learning the subject at schools must include implementing practical sessions that could develop student activities.

Avalos (2011) reported that a teacher learns to his professional side and achieve professional development activities as an additional part of his research. Competency in constructing design is part of pedagogical competence that can affect teacher performance (Sisdiknas, 2006). Competency in constructing design such as planning to conduct the activity, implementing, and assessing the practical activity. The competency in constructing design is able to impact the achievement of teachers and student who participate in the classroom (Veloo & Raman, 2013). The study of Sedova, Sedlacek and Svaricek (2016) found out that learning can be more effective if the students are active participants in the teaching and learning process.

Chemistry is one of the important subjects taught to educate students and teachers who are competitive in the globalization era (Depdiknas, 2007:46) through the development of varied competencies. Education is based on competency according to different teacher roles in the subject matter. As the focus in their competency-based curriculum, teachers do not play teacher-centered roles but practice a student-centered role. Quality relationship between teachers and students is important in maintaining harmony between both parties at school (Claessens, et al. 2016). The role and function of teachers as facilitators in the learning process focuses on discovering student ability to reach the recommended competency (Popham, 1998).

Teachers act as guide for students to achieve competency. Through design, implementation, and systematic assessment, teachers can play their role as facilitators and evaluators of student efficiency. However, students in Indonesia indicated less involvement in trial activities at the laboratory (Rahmawati & Hidayah, 2017). In addition, the observations by Copriady (2005) revealed that teachers fail at objectively assess the results of the trial performed by the students at the laboratory. Sinnadurai, Alyas and Rohani (2004) showed that teachers were not sufficiently efficient in organizing trial at the laboratory. Teachers must be competent in teaching and learning in learning environments especially in the classrooms (Liakopoulou, 2011) in addition to chemistry laboratory teachers.

Practical Activity in Chemistry Education

Teaching and learning of chemistry without practical motives result in poor understanding of actual phenomena while the practical sessions could help students to comprehend phenomena clearly. Practical sessions for chemistry help students see facts, data, and understand occurring phenomena realistically and clearly. Data from practical sessions can be analyzed for helping to explain phenomena (Azahari, 2003). The importance of practical sessions in the science laboratory is at par with the teaching and learning processes of science to enhance the performance (Hiang, 1998) and draw attention (Çepni, Ülger & Ormanci, 2017) in the science subject

Students are expected to benefit from chemistry practical sessions. These benefits include the increased motivation, understanding on scientific concepts and theories among students, development of skills in using practical tools, improvement in thinking skills, development of the scientific attitude and character, and improvement of creative thinking as well as personal and social character through the practice of scientific methods (Dawson, 2006). Chemistry teachers must be able to apply scientific methods. Science practical sessions consist of high mechanical and technical risks and enable to develop the ability of students to think and learn the truth through laboratory experiment. Teachers must be able to suggest, prepare, and perform the assessment for practical sessions.

Chemistry practical sessions are conducted for students to discover and prove theories (Kolomuc & Tekin, 2011), and students are asked to think logically and critically in analyzing a condition in practical instances (Dawson, 2006). Therefore, designing a program for chemistry practical sessions requires clear planning from teachers in the form of learning program report. Apart from designing such plan, teachers must be able to perform teaching and learning processes in the laboratory for practical learning environments.

In designing and implementing assessment for practical sessions, chemistry teachers face many challenges that require various solutions (Grounlund, 2000). Several problems include lack of skills in performing experiments and executing reports based on practical sessions. Such problems necessitate serious solutions to improve the mastery of teachers. Kassim (2004) stated that systematic investigation as an activity is necessary to improve skills in science activities and research. Thus, the manner requires further understanding in which practical sessions should be realized as part of learning chemistry. The science practical process can start with the teachers engaged in designing practical sessions, ways for students to conduct sessions with the guidance from the teachers, and assessment on how teachers assess student performance through their competencies.

Chemistry practical sessions are implemented by teachers in stages that cover constructing designs and preparing for and conducting practical sessions, as well as performing assessments. Designing is required by the teachers to conduct practical sessions for the sessions to be performed in accordance to the learning outcomes set beforehand. Aktamis and Acar (2010) highlighted the use of chemical laboratory to develop the conceptual understanding and skills of student as well as their cognitive and metacognitive competencies. Constructing the design for the practical sessions must be clear and related to many issues in chemistry covering what, why, and how such practical method is conducted and assessed. Practical activities should make students discover and prove a theory in the practical sessions as they are required to think logically and critically in analyzing a condition (Dawson, 2006).

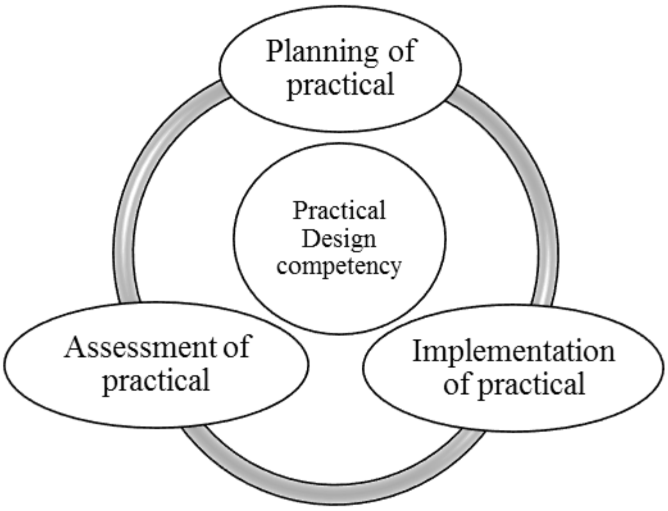


Figure 1. Theoretical Framework

Figure 1 represents the theoretical framework of the study. The three aspects are interrelated that are practical design, planning and implementation, and assessment. The teaching and learning processes is difficult through effective practical sessions in the laboratory. Hande, Kamath and D'Souza (2014) mentioned that effective teaching and learning processes are vital in improving student performance and (Özdemir & Işik, 2015) science skills of teachers. Besides, the process can be effective if the result can prove that students developed cognitively and effectively (Lorin, 2004). Therefore, effective teaching lessons in the laboratory will consist of a practical design that can explain in detail the planning, implementation, and assessment of practical sessions.

This study aims to determine the contribution of the chemistry teacher competency in Riau, Indonesia in terms of designing, planning, implementing, and assessing practical sessions. The contribution aims to illustrate chemistry practice in the laboratory within the aspects and to examine teacher perceptions on their chemistry teaching practice.

Definition

The practical design in practical learning by teachers aims to maximize understanding of teachers in applying their practical knowledge as a competency in planning and preparing laboratory trials. The process covers starting from understanding of teachers in designing a practical activity, planning to conduct the activity, implementing, and assessing such practical activity.

To explain further, the following details of the steps are based on the definition and purpose of the study:

a) Trial design
The construction of a chemistry practical design is the processes of arranging practical programs and other related components which are practical component materials, learning outcomes, arranging practical activities, deciding on practical purposes, and managing practical setting.
b) Trial planning
Chemistry practical activity planning is a process in preparing the tools, places, and materials necessary to conduct experiments.
c) Trial implementation
Chemistry practical activity implementation is the activity of performing practical teaching as planned. Implementation is an activity whereby teachers guide students in conducting trials.
d) Trial assessment
The chemistry practical activity assessment in the study is the manner of teachers observe and assess in the practical process as a whole to achieve the purpose of the practical activity. These activities include teacher assessment for accuracy of students in doing practical tasks, managing activities, and achieving practical results.

METHODS

A survey research design approach was adopted to identify the contribution of chemistry teacher competency in designing practical sessions, planning, implementing, and assessing. Survey research designs are procedures in quantitative research in which it provides researchers the opportunity to administer a survey to a sample or to the entire population of people to describe the attitudes, opinions, behaviors, or characteristics of the population (Creswell, 2014). In the current research, the population of this study consists of teachers from the general high schools in Riau Province Indonesia.

a) Study Sample

A total of 236 chemistry teachers from 11 districts in Riau, Indonesia participated in the study. The 48 (20.34 %) teachers were males and 188 (79.66%) were females. Approximately 80 (33.9%) teachers were from urban area and 156 (66.1%) teachers were from rural area. To decide the sample size, the researcher used the formula from Krejcie and Morgan (1970).

b) Study Instrument

A questionnaire was used in the study as the main instrument. The questionnaire has four constructs related to the design (24 items), planning (22 items), implementation (27 items), and assessment (29 items) of practical sessions. These items are based on instruments taken from Sampson (2004), Muijs and Reynolds (2001), and Meehan et al. (2004). Answers are chosen on a five-point Likert scale.

c) Statistical analysis

Inferential statistics, including regression, was employed to analyze the obtained data through SPSS 23.0 and AMOS 23. Structural Equation Model (SEM) was analyzed to identify teacher contribution on practical design, planning and implementation to assessment of practical exercise. Kline (2005) was suggested that model fit is excellent when the coefficient for comparative fit index (CFI) and Tucker-Lewis fit index (TLI) is greater than 0.95. Model fit for both is deemed adequate if the coefficient is greater than 0.90 (Byrne, 2010). For the root mean square error estimate (RMSEA), a coefficient less than 0.05 indicates an excellent fit and a coefficient under 0.08 indicates an acceptable fit.

d) Validity and Reliability

Analysis was conducted by calculating the internal validity and reliability of the research instrument. A pilot study was performed on 40 secondary school chemistry teachers from Pekanbaru. Based on the validity of the instruments, three validity tests were conducted on the research instrument of content, external, and instrument design. Based on the validity of the general result analysis, the instrument has a validity value of more than 0.30 in the aspects of practical design construction, preparation, implementation, and assessment, which means that the instrument has enough validity to use in this study. Hair et al. (1998) mentioned that a value of 0.30 is an acceptable value in factor analysis. Moreover, reliability analysis was carried out using Cronbach's alpha. The value of the Cronbach's alpha for the design, preparation, implementation, and assessment of practical sessions were 0.768, 0.774, 0.775, and 0.739.

FINDINGS

An analysis was done using the structural equation model (SEM) to determine contribution of teachers on practical design, planning and implementation to assessment of practical exercise. Results of the analysis showed that the measurement of the Chi Square/df = 4.43, *Root Mean Square Error Approximation* (*RMSEA)* = 0.061, *Goodness of Fit Index (GFI)* = 0.97, Tucker-Lewis fit index (TLI) = 0.97 and *Comparative Fit Index* (CFI) = 0.96. All types of evaluations have shown that the data used in this study were fit and compatible with the suggested model (Byrne, 2010). Results of the SEM showed that the suggested regression model was fit, since the teachers' practical design ($\beta = 0.13$, $p<0.05$), planning ($\beta = 0.629$, $p<0.05$) and implementation ($\beta = 0.42$, $p<0.05$) are significant predictor variables on assessment. Apart from that the SEM analysis showed a strong relationship between teachers' practical design, planning, and implementation ($r = 0.68 – 0.69$, $p<0.05$).

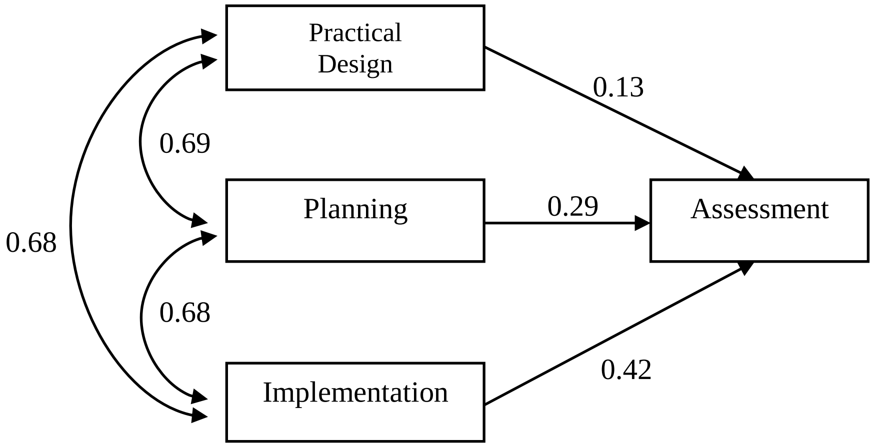


Figure 2. Contribution of teachers' practical design, planning and implementation to assessment of practical exercise

DISCUSSION

The present study aims to identify the contribution of competency in teacher design in lab practical sessions based on the planning, implementation, and assessment in conducting practical sessions at the chemistry laboratory in Riau. The findings showed that competency contributes in teacher design for practical sessions based on their preparation, implementation, and assessment. In addition, teachers found that knowledge can be applied during practical sessions at the science laboratory to provide in-depth and meaningful context of science (Dickson, Kadbey & McMinn, 2016).

Based on the analysis, a good teaching design is supported by enhanced preparation. Nurzatulshima (2008) said that a practical method could result in disorganization while there is lack of time management and good classroom control. Design for teaching chemistry involves considering the student ability to improve through practical sessions at the laboratory. According to Mugaloglu and Saribas (2010), science teachers are expected to construct enquiry design based on the subject that includes scientific process ability. Hodson (1993) provided evidence that supports the statement on conducting practical sessions to motivate, teach skills, improve learning ability, provide knowledgeable perspective, and develop learning attitudes such as thinking openly and objectively and preparing for decision making.

The analysis showed the teachers contribution on practical design, planning, and implementation to assessment of practical exercise. Such implementation is based on the practical design by teachers. Hilal and Esin (2010) stated that an effective teaching in science involves teachers who have the knowledge, skills, scientific attitude, and capability to meaningfully apply all related skills in the laboratory. The practical design used in the teaching and learning processes must be related to the curriculum. Science curriculum in teaching and learning must implicitly have practical sessions with their own approaches and methods. Tamir (1977) said that learning science is often conducted implicitly and not explicitly as part of its hidden curriculum as a subject and it is delivered by using language and methods used in the laboratory. How the implementation is considered effective is based on how far teachers achieve the purpose explicitly and implicitly.

The instruction of chemistry through practical activities is accomplished at the laboratory. According to Hakim et al. (2016), practical learning in the laboratories provide students with new knowledge and enhance their existing knowledge. Effective implementation of practical sessions must be supported by prior preparation of tools and materials, as these instruments are connected to existing facilities at the laboratory that students use later. The use of the laboratory can help to develop the student concepts, cognitive skills, and metacognitive competency. The enquiry approach and the use of chemistry laboratory increase conceptual development. Enquiry activities based on laboratory settings can potentially develop the conceptual skills of students (Hoftein & Lunetta, 2003). The preparation of tools and materials will define the effective implementation of practical sessions for improving the cognitive and psychomotor abilities of students.

After the implementation of practical sessions, the next step is to assess and analyze the experiment results. Teachers assess the overall student ability through detailed and clear analysis. In the National Research Council (2000), enquiry identification requires forming opinions, critical, and logical thinking in addition to consider alternative explanations. Thus, practical assessment requires the analysis of competency in producing practical result. An enhanced analysis provides direct understanding of the students by evaluating the errors they commit. The practical assessment looks at the affective attitude of students in the practical sessions because teaching does not only focus on the cognitive side but also on attitudes and skills. In studying science, students are attracted to learn from teachers and their cultivated interests (Jones, 1998). The development of positive scientific attitude among students must start from the positive perspective of teachers on science as practical. According to Talsma (1996), the attitudes of teachers toward science is vital in influencing the attitudes of students at every form. The scientific knowledge of teachers impacts their attitude which in turn affects scientific attitude. The positive attitude of science teachers influences their skills. Hence, teachers must develop a positive attitude on the practical sessions as examples for students. The teacher confidence also influence on the attitude and intention of the student (Weinburgh & Englehard, 1994).

Implıcatıons and Suggestions

The findings showed that competency in constructing design contributes toward competency in planning, implementation, and assessment. This relationship shows that design competency is an aspect to be considered and improved by chemistry teachers. Teachers as educators must have effective design competency such that the planning, implementation, and assessment to be performed well. Constructing and developing a design are particularly important in learning practical sessions. The government can continuously organize trainings and workshops on constructing and perform practical designs for chemistry for chemistry teachers. Such trainings and workshops can be organized by relevant parties, such as the Education Board, Education Quality Assurance Board, and Center for Development and Empowerment of Teachers and Education Personnel for teaching design construction of chemistry teachers. Overall, the focus will be on design competency in relation to the curriculum. Therefore, as part of curriculum planning, the Education Ministry must arrange relevant curriculum for improving the competency of chemistry teachers.

CONCLUSION

The study successfully proved the significant teacher contribution of practical design, planning, and implementation to assessment of practical exercise. The findings indicated that teacher competency in implementing practical sessions involves competency to construct design, perform practical sessions, teach practical activities in the laboratory, and assess practical sessions. The discussion revealed that practical design covers materials, purpose, practical preparation, and assessment. Practical design is important in performing practical sessions. However, the teacher competency in constructing practical and specific designs should be improved. The present study can be used as reference in assessing the competency of chemistry teachers in Riau, which could be used as a criterion for teachers to earn their professional teaching certificate. The study can be a guide in assessing the competency of chemistry teachers in Indonesia.

Acknowledgements

We are very grateful to Prof. Dr. T.Subhan Mohd Merah, Prof. Dr. Kamisah Osman and Prof. Dr. Lilia Halim for their critical comments and corrections. Moreover, Thanks to the faculty of teacher training and education and Rector of Riau University who provided the financial support for the research.

REFERENCES

Aktamis, H., & Acar, E. (2010). The effect of laboratory practices in science teaching course on development of prospective science teachers' self-regulation skills. *Procedia social behavioral science,* 2, 5549-5553.

Avalos, B. (2011). Teacher professional development in Teaching and Teacher Education over ten years. *Journal of Teaching and Teacher Education,* 27, 10-20.

Azahari, C.H. (2003). (*Live the glamour life as a Scientist*) *Kecapi Hidup Glamour Sebagai Saintis. Temubual dalam Chit-chat Saintis Tamu*. Estidot my. Ministry of Science, Technology and Environment. Kementerian Sains, Teknologi dan Alam Sekitar.

British Council Teachers' Federation (BCTF) & CUPE BC. (2009). *Roles and responsibilities of teachers and teacher assistants/education assistants.* A BCTF/CUPE Joint Paper. Retrieved from: http://bctf.ca/uploadedFiles/Public/Issues/InclusiveEd/RolesandResponsibilitiesTeachersTAs.pdf.

Byrne, B.M. (2010). *Structural equation modelling with AMOS: Basic concepts, applications and programming, (2nd ed.) Multivariate Applications Series.* New York: Routledge.

Çepni, S., Ülger, B.B., & Ormanci, U. (2017). Pre-Service Science Teachers' Views towards the Process of Associating Science Concepts with Everyday Life. *Journal of Turkish Science Education*, 14 (4), 1-15. doi: 10.12973/tused.10208a

Chochran, S.M. (2006). *Policy, practice and politics in teacher education. Editorial from the journal of teacher education*. California: A joint publication of Crown Press. Sage Publication Company and Serving Leader Thousand Oaks. p. XIIV.

Claessens. L., Tartwijk. J.V., Pennings. H., Want. W.V., Nico Verloop., Brok. P., & Theo Wubbels. (2016). Beginning and experienced secondary school teachers' self- and student schema in positive and problematic teacher student relationships. *Journal of Teaching and Teacher Education,* 55, 88-99.

Creswell, J.W. (2014). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. California: SAGE Publications, Inc.

Dawson, K. (2006). Teacher inquiry: a vehicle to merge prospective teachers' experience and reflection during curriculum based, technology enhanced field experiences. *Journal of Research on Technology in Education*, 38(3), 265–291.

Depdiknas. (2007). (Curriculum based on competency for chemistry subject) *Kurikulum Berbasis Kompetensi untuk mata pelajaran Kimia*. Jakarta. Jenderal Directorate of basic and secondary education. Direktorat Jenderal Pendidikan Dasar dan Menengah. Indonesia

Dickson, M., Kadbey, H., & McMinn, M. (2016). Correlating beliefs and classroom practices of public school science teachers in Abu Dhabi, U.A.E. *Journal of Turkish Science Education,* 13 (3), 161-172. doi: 10.12973/tused.10177a

Grounlund, N.E. (2000). *Measurement and evaluation in Teaching.* New York: Mac Milan Publishing Company Co, Inc.

Hakim. A. Liliasari, Kadarohman. A., & Syah. Y.M. (2016). Effect of the Natural product mini Project Laboratory on the students conceptual Understanding. *Journal of Turkish Science Education*, 13(2), 27-36. doi: 10.12973/tused.10165a

Hande, H.S., Kamath, S.R., & D'Souza, J. (2014). Students' perception of effective teaching practices in a medical school. *Education in Medicine Journal*, 6, (3) 63-66.

Hiang, P.S. (1998). (Science pedagogy: laboratory management and science sources) *Pedagogi Sains: Pengurusan Makmal dan Sumber Sains*. Kuala Lumpur. Kumpulan Budiman, Sdn. Bhd.

Hilal, A., & Esin, A. (2010). The Effect of "Laboratory practice in science teaching" course on development of prospective science teacher "Self-regulation skills". *Procedia Social and behavioral science*, 2, 5549-5553.

Hodson, D. (1993). Re-thinking old ways: Towards a more critical approach to practical work in school science. *Studies in Science Education*, 22, 85–142.

Hoftein, A., & Lunetta, V.N. (2003). The laboratory in science education: Foundation for 21st Century. *Science Education*, 88(1): 28-54.

Jones, H. (1998). *Engaging children in science*. Columbus, Ohia. 2nd edition.

Kassim, A.H. (2004). (Science practical perspective: scientific skills) "*Perspektif Amali Sains: Kemahiran Saintifik*". Education faculty, University Teknologi Malaysia: Unpublished.

Kline, R.B. (2005). *Principles and Practice of Structural Equation Modeling* (2nd Ed.). New York: The Guilford Press.

Kolomuc, A., & Tekin, S. (2011). Chemistry teachers' misconception concerning concept of chemical reaction rate. *Eurasian journal of physics and chemistry education*, 3(2), 84-101.

Krejcie, R., & Morgan, D. (1970). Determining sample size for research activities. *Educational and Psychological Measurement*, 30, 607–610.

Liakopoulou. M. (2011). The Professional Competence of Teachers: Which qualities, attitudes, skills and knowledge contribute to a teacher's effectiveness? *International Journal of Humanities and Social Science*, 1 (21), 66-78.

Lorin, W.A. (2004). *Increasing teacher effectiveness* (2nd Edition): Fundamentals of educational planning. Paris: United Nations.

Meehan, M.L., Cowley, K.S., Finch, N.L. Chadwick, K.L Ermolov, L.D. & Riffle, J.S. (2004). *Special strategies observations system-revised: A useful tool for educational research & evaluation.* Baltimore, MD: John Hopkins University.

Ministry of education and culture Indonesia. (2009). (Taken from Minister of Education's speech on academic qualification standard and teachers' competency) *Peratutan menteri pendidikan nasional (Permendiknas) Standar Kualifikasi akademik dan kompetensi guru no 16 tahun 2009*. Jakarta: Sinar Grafika. MOEC

Mugaloglu, E., & Saribas, D. (2010). Pre-Service Science Teacher's competence to design an inquiry-based lab lesson. *Procedia Social and Behavioral Sciences,* 2, 4255–4259.

Muijs, D., & Reynolds, D. (2001). *Effective Teaching: Evidence and Practice.* London: Paul Chapman Publishing.

National Research Council. (2000). *National Science Education Standards.* Washington, DC: National Academy Press.

Nurzatulshima, D. (2008). Management of Students' Involvement in Practical Science. *Malaysia Education Journal*, 34(1), 201-207.

Özdemir,O., & Işik, H. (2015). Effect of Inquiry-Based Science Activities on Prospective Elementary Teachers' Use of Science Process Skills and Inquiry Strategies. *Journal of Turkish Science Education*, 12(1), 43-56, doi: 10.12973/tused.10132a

Popham, W.J. (1998). *Educational Evaluation.* Englewood Cliffs, NJ: Prentice Hall.

Rahmawati, A.S., & Hidayah, F.F. (2017). Optimization of chemical laboratory functions in the learning process at SMA Negeri 9 Semarang. *National Seminar on Education, Science and Technology, Faculty of Mathematics and Natural Sciences, University of Muhammadiyah Semarang*, 56-63. ISBN: 978-602-61599-6-0

Sampson, V. (2004). The Science Management Observation Protocol. *The Science Teacher*, 71(10), 30-33.

Sedova. K., Sedlacek. M., & Svaricek. R. (2016). Teacher professional development as a means of transforming student classroom talk. *Journal of Teaching and Teacher Education,* 57, 14-25.

Sexton, S. (2015). Teaching the Future Teachers: A Teacher Educator's Self-Study in Making Science Relevant, Useful and Meaningful for New Zealand Pre-Service Teachers. *Journal of Education in Science, Environment and Health*, 1(1), 10-19.

Sisdiknas. (2006). Law of the Republic of Indonesia Number 14 Year 2005 About Teachers and Lecturers. Bandung: Citra Umbara.

Talsma, V.L. (1996). Science autobiographies: What do they tell us about preservice elementary teachers' attitudes towards science and science teaching? Paper presented at the Annual Meeting of the National Association for Research in Science Teaching. (St. Louis MO, April 2nd, 1996).

Tamir, P. (1977). How are the laboratories used? *Journal of Research in Science Teaching,* 14(4), 311-316.

Veloo, A & Raman, A. (2013). Methods of analysis & interpretation of data. Sintok: Universiti Utara Malaysia Press. ISBN 978-967-0474-19-9.

Weinburgh & Englehard, G. Jr. (1994). Gender, prior academic performance and beliefs as predictors of attitudes towards biology laboratory experiences. *School Science & Mathematics*, 94 (3),118–123.

Widyatiningtyas. R. (2004). (Teachers' role in doing assessment for processing skills) Peranan Guru Dalam Melakukan Penilaian Keterampilan Proses. *Educare, Jurnal Pendidikan dan Budaya,* 2 (2), 8-17.

TÜRK FEN EĞİTİMİ DERGİSİ
Yıl 15, Sayı 3, Eylül 2018

Journal of
TURKISH SCIENCE EDUCATION
Volume 15, Issue 3, September 2018

http://www.tused.org

A Confirmatory Factor Analysis of Malaysian Primary School Students' Energy Saving Practices

Hanifah, Mahat[1], Mohmadisa, Hashim, Nasir, Nayan, Yazid, Saleh & Saiyidatina Balkhis, Norkhaidi

[*] Department of Geography and Environment, Faculty of Human Science, Universiti Pendidikan Sultan Idris, 35900 Tanjong Malim, Perak, Malaysia, ORCID ID: 0000-0003-0756-6907

Received: 26.05.2017 **Revised:** 19.06.2018 **Accepted:** 30.08.2018

The original language of article is English (v.15, n.3, September 2018, pp.51-63, doi: 10.12973/tused.10237a)

ABSTRACT

This paper purposed to validate Malaysian primary school students' energy saving practices via confirmatory factor analysis. The sample of the study was a total of 401 primary school students, who were selected with randomly cluster sampling method. To collect data, a five-point Likert scale was used. Data were exposed to descriptive analysis (Cronbach's alpha values for reliability) and a confirmatory factor analysis for testing measurement models for each of the constructs through AMOS software. The results showed that Cronbach's alpha coefficient was higher than 0.70. The results of the first and second order confirmatory factor analyses (CFA) ensured that the collected data fit with the model. It was also found that the measurement model satisfied specified measurement criteria. Overall, it can be deduced that the extracted components are useful guidelines to increase Malaysian primary school students' understanding of energy saving practices. Further, this research recommends some implications for future research and practitioners.

Keywords: Confirmatory factor analysis (CFA), energy saving practices, measurement model, primary school students.

INTRODUCTION

Nature is a source of nutrition, oxygen, water, energy and production for human beings. Because raw materials come from natural environment, humans attain them for daily needs, i.e., nutrition and energy. Hence, this production process yields a product; however, a waste then pollutes natural environment (Hilal, 2011). In other words, even though nature recycles and transforms some wastes into raw materials, a greater amount of wastes pollutes natural sources (Invergard, 1976).

Air and environmental pollutions, which are well-known ones, result from the use of fossil fuels, e.g., coal, petroleum and natural gas, which are mostly used in industries, vehicles and domestic purposes (Sims et al., 2007). These fossil fuels particularly emit carbon dioxide and sulfur dioxide, which trigger air with environmental pollutants (i.e., lead). These gases

Corresponding author e-mail: hanifah.mahat@fsk.upsi.edu.my

© ISSN:1304-6020

react with water in the air and fall back to the earth as acid rain. Acid rain, which damages flora, fauna and buildings/infrastructures, causes water and environmental pollutions (Alpdogan, 1996). Furthermore, since the use of fossil fuels potentially brings about environmental pollution, energy production and consumption processes lead to destructive environmental pollution (Ayvaz, 1991). For these reasons, the consumption of energy sources not only emerges environmental problems but also threatens sustainable environmental development. Population growth, economic growth and high living standards have resulted in a steady increase in global energy consumption (approximately by two percent annually) (United States Department of Energy, 2016). By the end of the 21st century, this increase seems to be double.

A gradual increase in the technological use of energy makes energy an important issue. Thus, society is faced with energy consumption pressuretoday due to global energy crisis, climate change, and environmental degradation. Indeed, producing electricity through fossil fuels or using them for domestic heating are mainly responsible for half of pollution resulting in global warming. As a matter of fact, numerous national and international reports point to the importance of enacting immediate, dramatic and disaster coming from energy problem (Intergovermental Panel on Climate Change, 2013). In 2017, NASA published a study uncovering how fast Antarctica’s ice sheets were flowing into the ocean. Based on seven years of images (from 2008 to 2015), scientists found that glaciers were accelerating Antarctica’s Getz ice shelf into the southwestern part of the continent (NASA, 2017). This stems from an increase in the worldwide use of energy triggered by the sustained economic growth.

Energy consumption has been growing in such Asian countries as China, India, Indonesia, Malaysia or South Korea (Enerdata, 2017). For example; in Malaysia, a citizen’s home consumes approximately 251 kilowatt hours (kWh), which is equivalent to RM60.63 of electricity per month, releasing close to 171.68 kg of carbon dioxide (Malaysian Green Technology Corporation, 2015). To solve this problem, the Malaysian government has been made significant efforts with Go Green campaigns to address the importance of green behaviour and energy saving to society (Golnaz, Masoum, Mad Nasir, Ismail & Juwaidah, 2015). The Malaysia Energy Efficiency Action Plan was also framed to promote the efficient use of energy and minimize energy waste. Thus, this has contributed sustainable development and increased welfare and competitiveness (Ministry of Energy, Green Technology and Water Malaysia (KeTTHA), 2014). Therefore, the use of sustainable energy has been suggested for equatorial climate in Malaysia. All stakeholders have responsibilities to resolve energy consumption issues. This can be achieved by starting with the home and early childhood education.

Therefore, environmental education for energy issues may help students to cope with present and future energy needs and to shape their own attitudes, lifestyle practices and behaviors. The purpose of this paper was to validate the Malaysian primary school students’ energy saving practices via a confirmatory factor analysis.

Energy Saving in School

Environmentally preferable products, sustainability, green terms, and a decrease in the environmental footprint are a part of everyday life . Since energy efficiency is a very popular concept in the public and private sectors recently, environmental strategies and tactics have been designed to reduce its impact on the environment and human health (National Association of State Boards of Education, 2012).

Energy and its usage, one of the most important environmental issues, substantially affect economic and social development and qualified life in developing countries (Ntonaa, Arabatzis & Kyriakopoulosc, 2015). The risk of climate change and environmental degradation are in a parallel with globalized developmental processes and human interventions. The same thing is valid for educational institutions around the world even more at school (Nevzat, 2016).

School management is effectively in charge of the use of energy, although most of them have historically given little attention to control energy costs. Reducing wasted energy offers an excellent chance for minimizing a school's environmental footprint. For instance; turning unneeded lights off and decreasing other sources of wasted energy, students, staff and faculty may have an immediate impact on energy saving. Reducing electricity consumption is especially a ripple meaningful effect for the footprint of coal and gas-fired power plants, which is exaggerated by inherent system inefficiencies (Gülüzar, 2016). That is, approximately half of the fossil fuel consumed in power plants goes to production loss (Kate, 2013). Schools, which help students become environmental conscientious stewards and environmental friendly citizens, also have a very unique role in environmental protection. Any school-based environmental effortneed to maximize their roles in environmental protection (Anne, 2012).

Additionally, young students and children act as the true leaders in forging the way to attain a positive change for energy saving and reduce the financial and environmental burdens that accompany wasteful energy consumption. Thereby, students may find creative and innovative ways to engage their schools, families, peers and the community in disseminating energy awareness (Jo, Jennifer, Lani, Lorraine & Thach, 2012). Since children are decision-makers of the future, this population remains understudied for making any contribution to energy consumption. Schools can also equip students with conceptualizing and inspiring the importance of their reactions on environmental issues. Schools have an environmental footprint and generate trash. They use energy for heating, lighting, photocopying and so on. Schools are also cleaned using chemicals that have environmental impacts (Ikerne, 2013).

To encourage the implementation of an energy-saving eco school, an award called 'Sekolah Lestari' has been introduced by the Malaysian government. This award (addressing four main elements – management, greening activities, co-curriculum and curriculum) is hinged on an integrated approach that involves the school community, families, communities, government, private sector and non-governmental organizations. . This programme encapsulates current and planned environmental activities, such as the Wira Alam Project, Eco-Youth Programme, Renewable Energy and Energy Efficiency, Landscape and Beautification Programme, 3K Programme (Safety, Cleanliness and Beautification), Environmental Awareness Camp and other environmental activities (Ministry of Natural Resources & Environment, 2016). The Sekolah Lestari programme has possessed a transformative effect on Malaysian students' behaviors of towards environmental sustainability (Hanifah, Shaharudin, Mohmadisa, Nasir & Yazid, 2015).

Energy saving practices are theoretically related to the Social Practice Theory concentrating on the analysis of human behaviors , i.e., the use of energy and its consumption. Moreover, studies of sustainable energy saving practices refer to conceptual knowledge or conceptual understanding of environmental issues under investigation (Richmond & Morgan, 1977).

Therefore, this research deployed questionnaires to measure the Malaysian primary school students' knowledge of environmental sustainability regarding energy savings (e.g., electricity saving practices, water saving practices, nature-loving practices and 3R--reuse, reduce and recycle-- practices).Thus, this research measured the Malaysian primary school students' energy saving practices using a confirmatory factor analysis.

METHODS

a) Participants

Data were collected from 401 students (aged 10 to 12 years), which were selected from ten primary schools in the district of Batang Padang, Perak thourh a random cluster samplingmethod. A five-point Likert scale was administered by the researchers. Also, if necessary, they clarified any unclear issue in each item.

b) Developing the Questionnaire

The researchers firstly reviewed the related literature on the ‘energy saving’ concepts. Based on the literature review, an originally item pool was developed. The first draft of the scale consisted of four sub-factors – electricity saving practices, water saving practices, nature-loving practices and 3R practices. The sub-factors comprised of eight modified items from the energy saving practices outlined by the Ministry of Energy, Green Technology and Water Malaysia (KeTTHA) and the Association of Water and Energy Research (AWER). Then, the draft version was undergone an expert validity by four lecturers from the Universiti Pendidikan Sultan Idris dan Universiti Kebangsaan Malaysia. Further, its face validity was ensured with five Form 3 students.

A five-point Likert scale ranged from Strongly Disagree (one point) to Strongly Agree (5 points). Its Cronbach’s alpha values for all sub-factors clearly indicated acceptable levels (see Table 1) suggested by Cohen and Manion (1989). Further data were analyzed using SPSS 22.0™.

Additionally, the data were evaluated for unidimensionality of the items and the sub-scales through CFA using AMOS (Analysis of Moments Structure) (Arbuckle & Wothke, 1999), which is a statistical programme designed for performing structural equation modelling (SEM), a form of multivariate data analysis that can test for goodness-of-fit between research data and hypothesized models. AMOS calculates maximum likelihood (ML) estimates from a covariance matrix using several goodness-of-fit indices between the data and the specified model. Besides, Hair, Black, Babin, Anderson and Tatham (2006) recommended a number of goodness-of-fit indicators to test a hypothesized model. Assessment of model fit was based on multiple criteria, including both absolute misfit and relative fit indices.

The absolute misfit indices included the root mean square error of approximation (RMSEA), and the relative goodness-of-fit indices were the comparative fit index, the Tucker Lewis index and the incremental-fit index (CFI, TLI, IFI) (Hair et al., 2006). In view of Arbuckle and Wothke (1999), a model fits if the value of CMIN/df is between 1 and 5. Also, the CFI, IFI and TLI indices are acceptable fit for 1.00; a RMSEA index of 0.08 or less indicates a reasonable error, which is acceptable. The present study followed Hair et al.’s (2006) recommendations on the use of five indices at model fit: $\chi 2/df$, CFI, IFI, TLI and RMSEA. Table 1 shows the first order measurement for model fit of energy saving practices.

Table 1. Fit Indices for the Measurement Model

Fit Indices	Recommended values	Source
χ^2 / df	≤ 5.00	Hair et al. (2006)
TLI	≥ 0.90	Hoyle (1995)
IFI	≥ 0.90	Chau & Hu (2001)
CFI	≥ 0.90	Bagozzi & Yi (1988)
RMSEA	≤ 0.08	Browne & Cudeck (1993)

RESULTS and DISCUSSION

a) Reliability

Reliability is the accuracy and stability of the currency or marks of the scale of measurement (Hair, Anderson, Tatham & Black, 2010). In view of Sekaran and Bougie (2009), the higher the value is, the higher the alpha internal reliability is. This study set the value of Cronbach's alpha coefficients at 0.70 offered by Pallant (2010), Babbie (2007), and Hair et al. (2006). As seen in Table 2, the reliability values are are higher than 0.70. This demonstrates that the scale was acceptable. A confirmation factor analysis (CFA) was conducted on the four-construct-structure model using the Analysis of Moment Structure (AMOS 20.0™).

b) Fit Indices

As can be seen from Figure 1, the first order measurement model included a total of 401 Malaysian primary school students. The overall fit analysis for the measurement model showed the following values: Chi-square / df=1.558, CFI=0.889, TLI=0.888, GFI=0.923 and RMSEA=0.37. This indicated that the model was not fit for CFI, TLI value $\leq$ 0.90. Therefore, revisions were made for the model given guidelines by previous scholars (see Table 2).

Table 2. Revisions steps

Indicators	Cut-off	Description	Source
Normality			
• Univariate kurtosis and skewness values	± 2	Data do not violate the univariate normality assumptions	Garson (2012b)
• Mardia's coefficient/ multivariate kurtosis	1.96 or less	Nonsignificant kurtosis reveals significant normality. Thus, data do not violate the multivariate normality assumptions	
Outliers			
• Univariate outliers: standardized z score for large sample	≥ 4	Cases are outliers	Hair et al. (2010)
• Multivariate outliers: Mahalanobis distance (D^2)	Highest D^2 values (significant) *(α) is 0.001 or 0.005	D^2 values indicate significant for outliers at 0.005 level while those show extreme outliers at 0.001 level .	Hair et al. (2010) and Kline (2011)
Multicollinearity			
• Inter-construct correlation	>0.9	Multicollinearity problem exist	Hair et al. (2010)
• Standardized regression weight (factor loading)	Close ti 1	Multicollinearity problem exist	Garson (2012b)

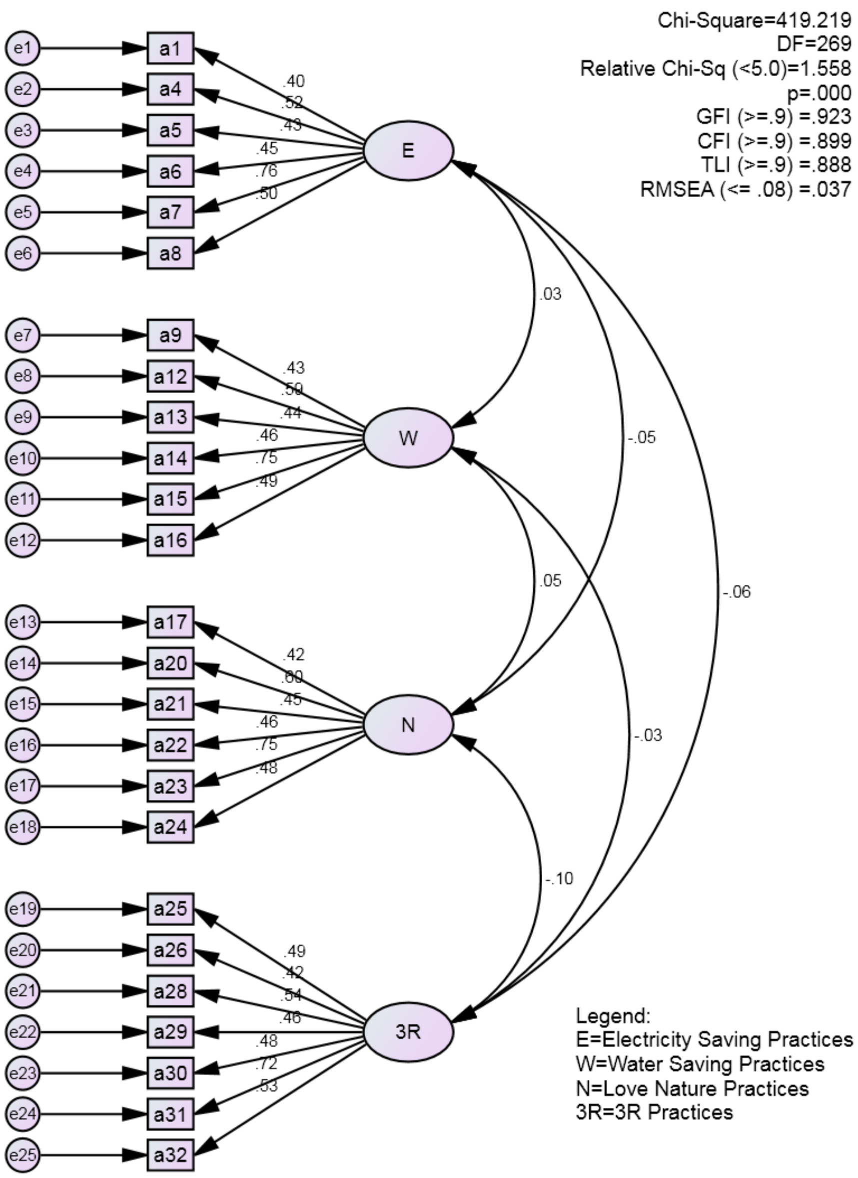


Figure 1: First Order Measurement Model before Revision

After revision, four items were dropped (see Figure 2). The revised model was tested again and the results of the CFA indicated a better fit. The goodness-of-fit indices for this model were as follows: Chi-square/df = 1.439, CFI=.935, TLI=.925, GFI= 0.941 and RMSEA=.034. This means an excellent model fit for the observed data. All paths between the latent sub-factors were statistically significant. The excellent model fit provided further evidence of the scale's validity.

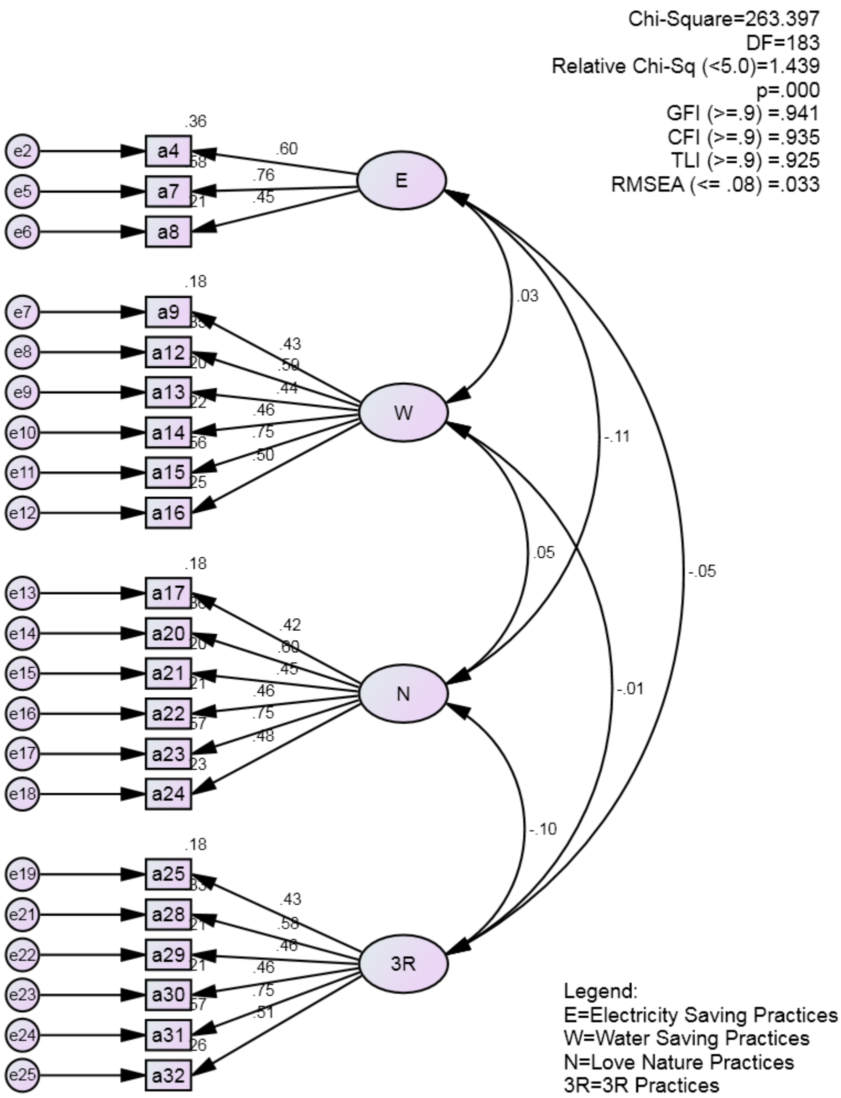


Figure 2: First Order Measurement Model after RevisionModification

As observed in Table 3, the correlations between all items were less than 0.90. This means no multicollinearity between constructs (Hair et al., 2006).

Table 3. Correlations between constructs

Constructs	Electricity Saving Practices	Water Saving Practices	Love Nature Practices	3R Practices
Electricity Saving Practices	1	0.03	-0.109	-0.048
Water Saving Practices		1	0.052	-0.014
Love Nature Practices			1	-0.097
3R Practices				1

Note: All correlations were significant at the 0.05 level.

Furthermore, convergent validity and discriminant validity were checked. Convergent validity is the degree to which multiple attempts to measure the same concept are in agreement. Convergent validity was assessed based on factor loading, composite reliability, and variances extracted (Hair et al., 2006). As can be seen from Table 4, the factor loading values for all items exceeded the recommended level of 0.50, which indicates categories of greater importance (Hair, 1998; Steven, 2003). Composite reliability values depicting the degree to which the construct indicators indicate the latent construct from 0.64 to 0.71 (see Table 4). The composite reliability of all latent constructs exceeded the recommended level of 0.60 (Hair et al., 2006). The extracted average variances were between 0.29 and 0.38. Moreover, discriminant validity is the degree to which the measures of different concepts are distinct. Discriminant validity can be examined through the squared correlations between constructs and the extracted variance for a construct (Anderson & Gerbing, 1988; Fornell & Larcker, 1981; Hair et al., 2006).

Table 4. Result of CFA for the measurement model

Construct	Item	Factor Loading	Composite reliability values	Extracted Average Variances
Electricity Saving Practices	a4	0.602	0.84	0.58
	a7	0.761		
	a8	0.455		
Water Saving Practices	a9	0.426	0.75	0.49
	a12	0.592		
	a13	0.445		
	a14	0.464		
	a15	0.747		
	a16	0.495		
Love Nature Practices	a17	0.425	0.77	0.59
	a20	0.601		
	a21	0.448		
	a22	0.462		
	a23	0.753		
	a24	0.483		
3R Practices	a25	0.429	0.71	0.53
	a28	0.578		
	a29	0.459		
	a30	0.455		
	a31	0.753		
	a32	0.514		

Afterwards, the second order measurement models were conducted to convert the constructs into indicators for measuring energy saving practices. The results (see Figure 3) came from a total of 280 Malaysian primary school students for the second order measurement model. The goodness-of-fit indices were as follows: Chi-Square/df=1.431, CFI=0.935, TLI=0.926, GFI=0.940 and RMSEA=0.33. This means that the model was fit (Figure 3).

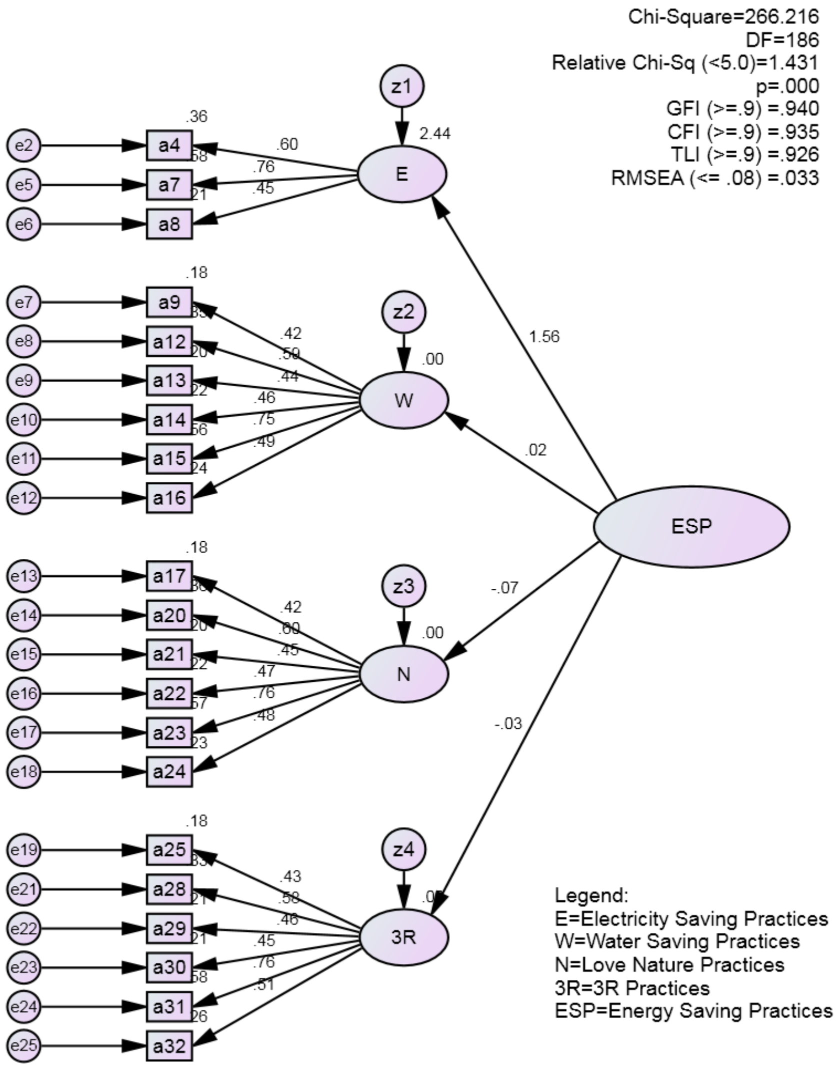


Figure 3: Second Order Measurement Model

As observed in Table 5, standardised loading, composite reliability and extracted average variance for all four indicators of energy saving practices exceeded the acceptable level (0.70) suggested by Hair et al. (2006).

Table 5. Standardised Loading, Composite Reliability and Extracted Average Variance

Construct	Item	Standardized Loading	Composite Reliability (CR)	Extracted Average Variance (EAV)
E	Electricity Saving Practices	1.562		
W	Water Saving Practices	0.02	0.75	0.51
N	Love Nature Practices	0.07		
3R	3R Practices	0.033		

CONCLUSION

This paper validated the Malaysian primary school students' energy saving practices via a measurement model. The results showed that the Cronbach's alpha value, which was higher than 0.70, was high and acceptable. This instrument had high reliability. The final model indicated four sub-factors of energy saving practices: electricity saving practices, water saving practices, nature-loving practices and 3R practices. Each item revealed a satisfactory loading value (more than 0.40). Also, the measurement model showed an adequate goodness-of-fit. The final model excluded five original items from 'electricity saving practices' sub-factor after the factor analysis. Similarly, a total of six items (two items per 'water saving practices, nature-loving practices and 3R practices' sub-factors).

Thus, the model developed was suitable for probing the Malaysian primary school students' energy saving practices. The preliminary results of the scale may shed more light on future comprehensive research eliciting students' energy saving practices. To generalize its validity and applicability, future studies should be conducted with larger samples. Also, further study can correlate the results with demographic features (i.e., gender, socio-economic level, type of school management).

ACKNOWLEDGMENTS

This study was funded by University Research Grant (GPU 2015-0114-106-01) at the Universiti Pendidikan Sultan Idris. The authors would like to thank the Universiti Pendidikan Sultan Idris for the research funds, participants and school principals.

REFERENCES

Alpdogan, T. (1996). Air and environmental pollution providing a solution to prevent immediate results: Thermal insulation. *Turkey Eng. News*, pp. 8–10.

Anne, O. (2012). Act and inspire: The dual roles of schools in environmental protection. Retrieved from http://www.edutopia.org/blog/environmental-ed-lessons-anne-obrien

Arbuckle, J., & Wothke, W. (1999). *AMOS 4 user's reference guide*. Chicago: Smallwaters Corp.

Ayvaz, Z. (1991). Energy, economy, entropy, and environmental pollution. *J. Ecol*, 1(1991), 22–23.

Babbie, E. (2007). *The practice of social research*. Belmont, California: Thomsom Wadsworth.

Cohen, L. & Manion, L. (1989). *Research methods in education* (3rd ed.). London: Routledge.

Enerdata. (2017). Global Energy Statistical Yearbook 2017. Retrieved from https://yearbook.enerdata.net/total-energy/world-consumption-statistics.html

Enerdata. (2017). Global energy statistical yearbook 2018. Retrieved from https://yearbook.enerdata.net/total-energy/world-consumption-statistics.html

Golnaz, R., Masoum, H., Mad Nasir, S., Ismail, A. L., & Juwaidah, S. (2015). Effects of go-green campaigns on changing attitude towards green behaviour. *Social Sciences and Humanities*, 23(8), 77–92.

Gülüzar, E. (2016). Developing energy systems engineering students' perceptions of renewable energy for sustainable future. *Journal of Turkish Science Education, 14*(2), 42-51.

Hair, J. F., Anderson, R. E., Tatham, R. L., & Black, W. C. (2010). *Multivariate data analysis* (4rd ed.). New Jersey: Prentice Hall.

Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (2006). *Multivariate* *data analysis* (6th ed.). New Jersey: Prentice Hall.

Hanifah, M., Shaharudin, I., Mohmadisa, H., Nasir, N. & Yazid, S. (2015). Transforming sustainability development education in malaysian schools through greening activities. *Review of International Geographical Education Online (RIGEO)*, 5(1), 77-94.

Hilal, A. (2011). Determining energy saving behavior and energy awareness of secondary school students according to socio-demographic characteristics. *Educational Research and Reviews*, 6(3), 243–250.

Ikerne, A. B. (2013). *Electricity saving behaviours and energy literacy of New Zealand children*. University of Otago, New Zealand.

Intergovernmental Panel on Climate Change (IPCC). (2013). *Summary for policymakers*. Cambridge, United Kingdom and New York, US: Cambridge University Press.

Invergard, T. B. K. (1976). Ergonomics and the Consumer. *Ergonomics*, 19(3), 321–329.

Jo, T., Jennifer, A., Lani, W., Lorraine, G., & Thach, S. (2012). *Energy saving success stories from Southern California 2011-2012*. Washington, DC.

Kate, C. (2013). *Powering Down*. Antioch University New England: Resource Management and Conservation.

Malaysia Environmental Department (2016). *Sekolah Lestari – Environmental Award*. Retrieved from http://www.doe.gov.my/portalv1/en/info-umum/sekolah-lestari-anugerah-alam-sekitar/163

Malaysian Green Technology Corporation. (2015). *A touch of green: Save money, save energy, save the planet*. Retrieved from http://www.themalaymailonline.com/features/article/a-touch-of-green-save-money-save-energy-save-the-planet.

Ministry of Energy, Green Technology and Water Malaysia (KeTTHA). (2014). *National Energy Efficiency Action Plan*.

NASA. (2017). *Responding to Climate Change*. California Institute of Technology. Retrieved from https://climate.nasa.gov/solutions/adaptation-mitigation/

National Association of State Boards of Education. (2012). *The State Education Standard*. Retrieved from http://www.nasbe.org/our-resources/publications/the-state-education-standard/.

Nevzat, Y., Muhammet Mustafa, A., Yasi,n C.& Bilal, B.(2016). Examine middle school students' constructivist environment perceptions in Turkey: School location and class size. *Journal of Turkish Science Education, 14*(1), 23-34.

Ntonaa, E ,Arabatzis, G. & Kyriakopoulosc, G.L. (2015). Energy saving: Views and attitudes of students in secondary education. *Renewable and Sustainable Energy Reviews, 46*, 1-15.

Pallant, J. (2010). *SPSS survival manual: A step by step guide to data analysis using SPSS (4th ed.)*. Maidenhead: Open University Press/McGraw-Hill.

Richmond, J. M., & Morgan, R. F. (1977). *A National Survey of the Environmental Knowledge and Attitudes of Fifth Year Pupils in England*. Columbus, Ohio: ERIC/SMEAC Information Reference Center.

Sekaran, U., & Bougie, R. (2009). *Research Methods for Business: A Skill Building Approach (5th ed.)*. United Kingdom: John Wiley & Sons Ltd.

Sims, R. E. H., Schock, R. N., Adegbululgbe, A., Fenhann, J., Konstantinaviciute, I., Moomaw, W., Zhang, X. (2007). *Energy supply. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, United Kingdom and New York: Cambridge University Pres.

United States Energy Information Administration (EIA) (2016). *International energy outlook 2016*. Washington, DC.

Appendix

SCALE

Malaysian Primary School Students' Energy Saving Practices

PART A: DEMOGRAFIC FEATURES

INSTRUCTIONS:
Please fill in the blank.

Name : ______________________
School : ______________________
Year : ______________________
Gender : ______________________
Ethnics : ______________________

PART B: ENERGY SAVING PRACTICES

INSTRUCTIONS:
For the following questions, please rate the items on a scale of 1-4.
1 for 'never', 2 for 'sometimes', 3 for 'frequently' and 4 for 'very often'.
Round on your preferred answer.

Electricity Saving Practices

a1	I switch off the light when not in use	1	2	3	4
a2	I switch off the fan when not in use	1	2	3	4
a3	I switch off the fan when it rains or cold weather	1	2	3	4
a4	I let the television open even if not used *	1	2	3	4
a5	I switch off the hand phone charger when not in use	1	2	3	4
a6	I shut down the computer when not in use	1	2	3	4
a7	I switch off the bedroom light before going to bed	1	2	3	4
a8	I leave the refrigerator door open even if it does not take any items *	1	2	3	4

Water Saving Practices

a9	I close the tap water while washing my hand	1	2	3	4
a10	I close the tap water when brushing teeth	1	2	3	4
a11	I close the tap water during hair shampoo	1	2	3	4
a12	I let the tap water drain when washing plates / cups *	1	2	3	4
a13	I take a shower for a long time*	1	2	3	4
a14	I flush the toilet when it is necessary only	1	2	3	4
a15	I let the tap water flow while brushing school shoes *	1	2	3	4
a16	I use rain water to help my family member wash their cars / motorcycles	1	2	3	4

Love Nature Practices

a17	I swept if there was a garbage in school or at home	1	2	3	4
a18	I dump trash everywhere *	1	2	3	4
a19	I love planting trees	1	2	3	4
a20	I use soap and shampoo that is shared with family members	1	2	3	4
a21	I help watering the trees in the morning and evening	1	2	3	4
a22	I like to burn rubbish *	1	2	3	4
a23	I did not step on the grass in the area that was prohibited by the school	1	2	3	4
a24	I do not pick leaves / flowers at will	1	2	3	4

3R Practices

a25	I store food in recyclable containers	1	2	3	4
a26	I use handkerchief instead of tissue	1	2	3	4
a27	I remove waste that can be recycled into the recycle bin	1	2	3	4
a28	I sell or donate unnecessary clothing	1	2	3	4
a29	I use a rechargeable battery	1	2	3	4
a30	I use old note books that are still good for school use	1	2	3	4
a31	I sell or donate old books that are not used anymore	1	2	3	4
a32	I use the pencil until shortest size	1	2	3	4

Thank you for responding to this questionnaire

TÜRK FEN EĞİTİMİ DERGİSİ
Yıl 15, Sayı 3, Eylül 2018

Journal of
TURKISH SCIENCE EDUCATION
Volume 15, Issue 3, September 2018

http://www.tused.org

Using an Explicit NOS Flow Map in Instruction of Nature of Science Based on the Science of Philosophy

Hun-Young OH[1], Norman G. Lederman [2]

[1] Hanyang University, Seoul 133-791, Republic of Korea, ORCID ID: 0000-0001-6418-197
[2] Department of Mathematics and Science Education, Illinois Institute of Technology, Chicago, IL 60616, USA

Received: 27.07.2017 **Revised:** 04.07.2018 **Accepted:** 17.07.2018

The original language of article is English (v.15, n.3, September 2018, pp.64-90, doi: 10.12973/tused.10238a)

ABSTRACT

The purpose of this study is to develop a flow map for history of science instruction on nature of science (NOS) using a cognitive strategy. This is done to enhance overall scientific literacy through specificity and reflectiveness, and to examine pre-service elementary teachers' understanding of the NOS using NOS flow maps concerning Galileo's discovery of sunspots. There exists a general consensus in the science education literature regarding the goal of enhancing learners' views of the NOS. An extensive body of research in the field has highlighted the effectiveness of explicit NOS instructional approaches in improving learners' views on the NOS. Because it is valuable to introduce elementary students to some of the ideas developed by Kuhn, pre-service elementary teachers' understanding of the NOS was explored using an explicit NOS flow map developed as an instructional tool. The lessons combined cognitive conflict strategies in episodes concerning the history of science (Galileo's discovery of sunspots) with accompanying responses consisting of illustrations and questions. The lessons were designed to spend 50 minutes on study of the history of science, including conflict strategy, and 30 minutes on an explicit NOS flow map including all elements of the NOS. Students demonstrated understanding of tentativeness of scientific knowledge, and the lack of a universal scientific method. Therefore, instruction based on an NOS flow map is a promising method to enhance science teaching and learning.

Keywords: Cognitive strategy, Copernican Revolution, history of science, Kuhn's philosophy, nature of science.

INTRODUCTION

Scientific literacy requires an understanding the nature of science (NOS), the scientific enterprise, and the role of science in society and personal life (NRC, 1996, p. 21). Despite promotion of the potential benefits of NOS instruction and widespread endorsement by the science education community, research has consistently shown that K-16 students do not attain the desired comprehension (Lederman, 2007). Understanding the conceptions and beliefs of pre-service teachers (PSTs) about the NOS is important for improving the actions and activities developed in PST training courses (Colagrande, Martorano, & Arroio, 2016).

The history of science (HOS) approach employs episodes from scientific history to illustrate various aspects of the NOS. The implicit approach emphasizes doing science, assuming that participation in authentic scientific investigations will help students develop

Corresponding author e-mail: jyoh3324@hanyang.ac.kr

© ISSN:1304-6020

more accurate understanding of the nature of scientific inquiry and knowledge. The explicit approach specifies that instructional goals related to the NOS “should be planned for instead of being anticipated as a side effect or secondary product” (Akindehin, 1988, p.73)

Abd-El-Khalick and Lederman (2000a) emphasize the following:

> The relative ineffectiveness of the implicit approach could be attributed to two inherent assumptions. **The first** is that attaining an understanding of NOS is taken to be a ***cognitive*** **learning outcome**. **The second** ensuing assumption is that learners would *necessarily* develop understandings of NOS as a by-product of engaging in science-related activities. They should be able to use examples and/or ***simplified case histories*** from scientific practice to substantiate this claim and make it accessible and understandable to students. (p. 665)

Using HOS as a context for science instruction provides students with more opportunities for reflection, discussion, and deep critical thinking. Further, teachers without the requisite understanding of the NOS are likely to promote absolute views, the knowledge aspects of science (Gess-Newsome, 1999). These science educators ignore the role of creative ideas in the production of science knowledge (Duschl, 1990), and may hinder students in developing the correct perspective on science. To overcome this, Bell, Matkins, and Gansneder (2011) have claimed that understanding of the NOS could be improved by introducing argumentation, and more recently, Bakırcı, Çalık, and Çepni (2017) claim that understanding of the NOS could be based on the Common Knowledge Construction Model (CKCM). However, because HOS can directly show the impact of scientific knowledge on culture and society at a certain time (Solomon, Duveen, Scott, & McCarthy, 1992), it can effectively illustrate the scientific research process.

In contrast to reports of the positive effect of HOS instruction on understanding the NOS, some cases with almost no effect have also been reported (Abd-El-Khalick & Lederman, 2000a; Tao, 2003). HOS is presented in the form of data records or lectures in classes with HOS as its subject matter. However, the students in general tend to comprehend the historical information in terms of their own perspective, without regard for the historical standpoint—in other words, the contemporary social state or worldview (Abd-El-Khalick & Lederman, 2000a). Therefore, mere introduction of HOS to NOS instruction does not guarantee students’ understanding of the NOS. It is necessary to develop a tool for explicit NOS instruction that not only directly incorporates the research efforts of scientists and the social and cultural impacts to the historical context, but also functions as a bridge to the modern history of science. In short, the NOS must be made explicit within historical case studies.

Scientific literacy encompasses an understanding of both science content knowledge (SCK) and the NOS. School science, however, tends to focus only on teaching SCK, often ignoring the NOS (Clough, 2006). Many students’ ideas parallel early historical scientific ideas, suggesting that “alternative conceptions” may sometimes be a better descriptor than “misconceptions.” Classical Conceptual Change Theory arose from both Piaget’s theories of children’s thinking and Kuhn’s HOS work (referred to in this study as “case studies”), as well as work in science education on students’ and teachers’ preconceptions (Oh, Lee, & Lee, 2017; Zohar & Aharon-Kravetsky, 2005; Torres, Moutinho, & Vasconcelos, 2015).

Cognitive conflict has been considered an important factor in learning since the days of Piaget. He believed that when children’s interactions with the world result in experiences that do not fit their current conceptions, their mental balance is disturbed (i.e., a cognitive conflict occurs). Cawthron and Rowell (1978) drew parallels between Kuhn’s findings and Piaget’s theory of knowledge and psychological account of constructive knowing.

Naturally, there are constraints on what can be achieved in terms of affecting elementary teachers' conceptions of the NOS in the context of science methods courses. These include time constraints, the extended agendas of the courses, and elementary teachers' limited knowledge of science content and experience with science (Akerson, Morrison, & McDuffie, 2005; Morrison, Raab, & Ingram, 2009). Abd-El-Khalick and Akerson (2004) found that an explicit-reflective approach to instruction was even more effective in improving elementary teachers' views of the NOS when undertaken within an orthodox conceptual change model (CCM) framework of learning (Hewson, Beeth, & Thorley, 1998; Posner, Strike, Hewson, & Gertzog, 1982).

In this study, we consider how the NOS has relates to the philosophy of Kuhn. We then identify the ways in which a historical science case (a science study) can embody the key elements of the NOS, suggest the instructional sequence for an explicit NOS flow map as a *cognitive resolution,* and examine PSTs' views of the NOS using the case of Galileo's discovery of sunspots, an example of the Copernican Revolution.

BACKGROUND

An explicit NOS flow map for aspects of the NOS through the new philosophy and conceptual change model

According to Eflin, Glennan, and Reisch (1999),

> It is valuable to introduce students at an elementary level to some of the ideas developed by Kuhn. In particular, students benefit by considering the idea that different paradigms compete with each other, and that they can easily understand some of the ways in which theoretical commitments and social issues can influence the development of science. On the other hand, students should be made aware that some interpretations of Kuhn's views are extreme and not persuasive (radical incommensurability). (p. 114)

Thus, even if we are unwilling to accept Kuhn's incommensurability thesis, we should recognize that learners should make a genuine effort and extended commitment to achieve the conceptual shift necessary to make the historical approach useful for science learning (Abd-El-Khalick & Lederman, 2000b).

The middle-of-the-road approach is suggested by some of the NOS tenets given in American Association for the Advancement of Science (AAAS) reports. Regarding this middle-of-the-road approach to Kuhn's works, Loving and Cobern (2000) state the following:

> An important portrait of Kuhnian works about the nature of science deals with the theory-ladenness of observations. The notion of the theory-ladenness of observations in science is one of the least controversial aspects of current views of the nature of science. The degree of interference and the extent to which interpretations of observations are controlled by existing knowledge varies in writings from the extremes of Feyerabend to Toulmin to the relatively conservative acknowledgements of Shapere and Laudan, Kuhn is somewhere in the middle on this continuum, but his widely read *SSR* probably serves as a primary source of support for most on this issue. (p. 190)

Despite continuing disagreement on a single definition for the NOS, at a certain level of generality and within a certain time period, wisdom about the NOS is shared. Considering issues related to student accessibility, public recognition, and usefulness to citizens, Lederman (2007) has proposed the following:

> Seven key aspects of NOS: Scientific knowledge is **tentative** (subject to change), **empirically** based (based on and/or derived from observations of the natural world), and **subjective** (involves the personal background, biases, and/or is **theory-laden**); necessary involves human inference, imagination, and **creativity** (involves the invention of explanations); and is **socially and cultural** embedded. Two additional important aspects are the distinction between **observation and inferences**, and the functions of and relationships **between theories and laws**. (p. 53)

We insist that none of these aspects should be considered independently of the others. Thus, these key aspects of the NOS are viewed in this study as interdependent, dynamic, explicit, and reflective (see Figure 1). Empiricists argue that our human perceptions give us objective facts about the world that form the foundations of science; general laws and theories are inductively produced based on those facts. However, human perception is not objective. Judgments and inferences on observable facts in specific situations vary depending on the person, the culture, and the theoretical school.

That is, with respect to social and cultural background and the social dimension, perception is formed and developed in a decisive manner by the subjectivity of observers: their cultural and theoretical background, their expectations, and their perspectives. This consideration falls under “the theory-ladenness of observation” in the philosophy of science. Additionally, empiricists say that law, which demonstrates regularity, and theory, which requires creativity, should be separated. Because of the theory-ladenness of observation, we insist that law and theory should be dynamic rather than distinct from one another. Similarly, most modern philosophers of science have questioned the hierarchical/dichotomous relationship between laws and theories (Giere, 1999; Niaz & Maza, 2011, p. 5). The development of scientific knowledge involves making observations of nature. That is, observations are not “scientific methods” represented by induction. Finally, because an objective law or theory is not produced from objective facts, a scientific theory is, indeed, *tentative*.

The lack of consensus over fundamentals distinguishes mature, “normal” science from the relatively disorganized immature pre-science. According to Kuhn, immature pre-science is characterized by total disagreement and constant debate over fundamentals. There will be almost as many theories as there are workers in the field.

The disorganized and diverse activity that precedes normal science eventually gains structure and direction when a single paradigm emerges, adhered to by the scientific community. Kuhn describes formal science as “puzzle-solving,” because problems are solved within the terms of the paradigm. With respect to a paradigm, an unsolved problem is simply an anomaly, fodder for future researchers. In periods of normal science, the paradigm is not open to serious question. Nothing good lasts forever, however, and that includes normal science. Anomalies accumulate, and may eventually be seen as real problems rather than mere puzzles. Kuhn terms this “a period of crisis” (Sismondo, 2004, p. 13).

If an alternative is presented that solves some of the accepted paradigm’s central unsolved questions (for example, experimentation yields a new paradigm candidate, and the *seriousness of a crisis deepens*), then some scientists, particularly younger scientists who have not yet been fully indoctrinated into the beliefs and way of life of the older paradigm, will adopt the alternative. Eventually, a robust alternative may become a paradigm itself, structuring a new period of normal science through paradigm shift, or extraordinary or revolutionary science.

In *The Essential Tension* (Kuhn, 1977), Kuhn discusses the relations of cognitive structures and learning conditions for learning of scientific knowledge. It was important components in establishment of a paradigm in which learning, cognitive apprenticeships, and transmission of basic concepts and methodologies were.

Classical conceptual change theory arose from Piaget's theories of children's thinking and Kuhn's history of science work. The Piaget theory of the development of cognitive structure ("Kuhn's paradigm") suggested that disequilibrium or cognitive dissonance with respect to the initial conception must be created within an individual to facilitate learning (Rea-Ramirez, Clement, & Nŭňez-Oviedo, 2008, p. 24).

Cawthron and Rowell (1978, p. 46) first linked Kuhn's ideas on the noncumulative, discontinuous grow of scientific knowledge with Piaget's views of the staged development of individual cognition.

Thus, both the worldview and the developmental level of an individual are determined by a dialectic process whereby a dynamic equilibrium is nonstatic, and new cognitive structures evolve through the dialectic process (known as "equilibration" in Piagetian terms).

An explicit approach might not suffice to substantially change students' entrenched conceptions of the NOS. An orthodox conceptual change model approach (Posner et al., 1982; Oh, 2017; Abd-El-Khalick & Akerson, 2004) might be more effective, as suggested by Abd-El-Khalick and Lederman (2000b):

> Students' views of certain NOS aspects are first elicited. Next, specific historical examples are used to help students discern the inadequacy of, and raise their dissatisfaction with some of their current NOS conceptions. Students are then explicitly presented with more adequate conceptions of Target NOS aspects. The historical narrative (cases) can then be employed to provide students with opportunities to perceive the applicability and fruitfulness of these newly articulated views in making sense of various aspects of scientific knowledge and practice in a variety of historical and disciplinary. (p. 1089)

The CCM also assumes that "ontogenetic change in an individual's learning is analogous to the nature of change in scientific paradigms that is proposed by philosophers of science" (Pintrich et al., 1993, p. 169). Conditions necessary for conceptual change to occur are dissatisfaction with existing conceptions, intelligibility of a new competing conception, plausibility, and fruitfulness. Posner et al. imply that in raising the status of a new conception, the above conditions will be fulfilled in a linear fashion, starting with dissatisfaction with the existing scientific conception and proceeding to the new conception's fruitfulness (Tyson et al., 1997).

In Figure 1, the dark orange section, "social and cultural effects," relates to *dissatisfaction*; the "subjective" light orange section, which describes certain scientific activities, relates to *intelligibility*; the remaining light orange sections, describing scientific activities, and the yellow sections, describing the scientific products of these activities, relate to the *plausibility* and *fruitfulness* of a suggested concept. The white section describes the overall result of these conditions: the tentativeness of scientific knowledge, turn out through dissatisfaction, specifically social and cultural pressure.

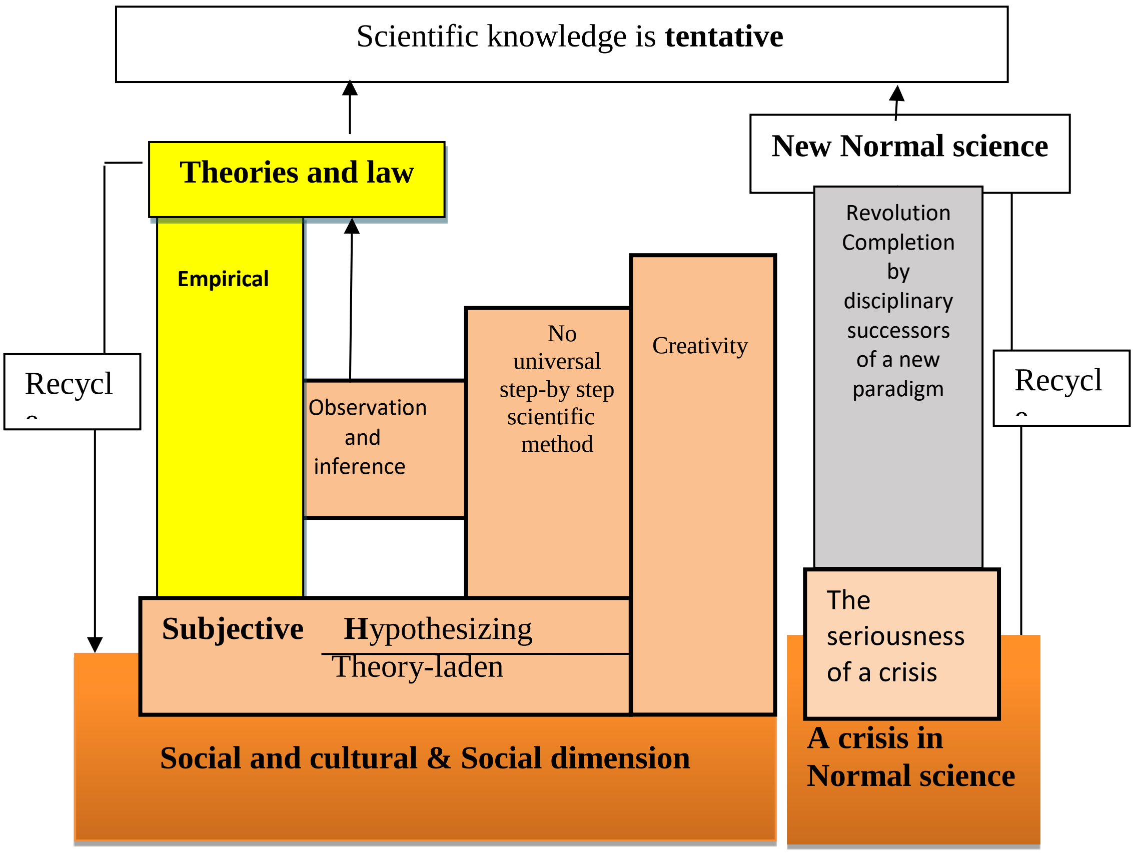


Figure 1. *Relationship between NOS and Kuhn's Scientific Revolution (Modified from Oh, 2017)*

Generation of cognitive conflict: dissatisfaction with existing conceptions

A crisis in normal science arises due to a number of serious anomalies. (The social and cultural embeddedness of scientific knowledge and the crisis of Kuhn's normal science.) Science as a human enterprise is practiced within a larger cultural context, and its practitioners are products of that culture. Thus, it follows that science affects and is affected by the various elements and intellectual spheres of the culture in which it is embedded (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). Therefore, anomalies are regarded as *serious* if they are important with respect to some pressing social need. Also affecting the seriousness of an anomaly is the length of time it resists attempts to remove it (Chalmers, 1990, p. 113).

Resolution of cognitive conflict: intelligibility of the new competing conception, plausibility, and fruitfulness

The seriousness of a crisis deepens due to the appearance of an alternative. (Subjective: The theory-laden nature of scientific knowledge and the seriousness of Kuhn's normal science crisis.) Observations (and investigations) are always motivated and guided by questions or problems, and they acquire meaning with reference to these questions or problems, which are derived from certain theoretical perspectives (Lederman et al., 2002). According to Kuhn, a new paradigm, or a sufficient hint to permit the articulation of a new paradigm, emerges suddenly, sometimes in the middle of the night, in the mind of a man deeply immersed in crisis (Chalmers, 1990, p. 114).

Revolution by disciplinary successors of a new paradigm

Through the continuous study of disciplinary successors, additional empirical observations accumulate to resolve serious anomalies, and through the new observations and inferences developed to explain them, new laws and theories are generated.

Observations are descriptive statements about natural phenomena that are directly accessible to the senses (or extensions of the senses), and about which observers can reach consensus with relative ease. By contrast, **inferences** are statements about phenomena that are not directly accessible to the senses (Hull, 1998, p. 146).

Scientists derive specific, testable predictions from theories and check them against tangible data. Closely related to the distinction between observation and inference is the distinction between scientific theories and laws. In general, laws are descriptive statements of relationships among observable phenomena. Theories and laws are different kinds of knowledge, and one does not become the other. However, we insist that laws (which demonstrate regularity), like theory, are a function of human creativity and should be considered in a dynamic rather than separate way because of the theory-ladenness of observation. As Niaz and Maza (2011) state:

> Researchers in current science education also questioned the dichotomy between theories and laws (McComas et al. 1998). Scientific progress is characterized by a series of theories or models (plausible explanations), which vary in the degree to which they explain/interpret/predict the experimental findings. (p. 5)

According to Kuhn's philosophy, which recognizes the theory-ladenness of observation, the relationships between the empirical facts involving anomalies, inferences, and scientific theories are dynamic rather than linear. As Brown (1977) states:

> Only after Researcher has learned to see reality in terms of acceptable theory is research possible, but it is also possible for the researcher to discover anomalies and thus come to reconsider acceptable theories … Theories often provide a definite description of what the scientist ought to see and thus sharpen his vision for the discovery of anomalies. And as long as the scientist is carrying on empirical investigation it is not theory alone which determines what will actually occur, but theory in conjunction with a theory-independent world … It is the recalcitrant anomalies that eventually lead to the overthrow of one theory and its replacement by another… (pp. 108-–109).

The development of scientific knowledge involves making observations of nature. Nevertheless, generating scientific knowledge also involves human imagination and creativity (Lederman et al., 2002). Creativity is necessary for all inquiry procedures, based on all key aspects of the NOS. One of the most widely held misconceptions about science is the existence of a scientific method. There is *no single scientific method* that guarantees the development of infallible knowledge (AAAS, 1993; NRC, 1996).

Factors such as Kuhn's scientific revolutions involve a change, not just in the range of claims made but also in the kinds of entities (theories) that are assumed to constitute the world and the kinds of evidence and modes of explanation that are deemed appropriate. Such changes arise through a great deal of creativity on the part of disciplinary successors of a new paradigm.

A new stage of normal science and its recycling (expansion)

After a scientific revolution by disciplinary successors is completed, a new paradigm emerges. Scientific knowledge, although reliable and durable, is never absolute or certain. This knowledge, including facts, theories, and laws, is subject to change. Scientific claims change as new evidence, made possible through advances in thinking and technology, is brought to light, and as extant evidence is reinterpreted in light of new theoretical advances, changes in cultural and social spheres, or shifts in the direction of established research programs.

Tentativeness in science does not arise solely from the fact that scientific knowledge is inferential, creative, and socially and culturally embedded.

Because the flow map we developed is closely connected to Kuhn's scientific revolution (cognitive resolution and the history of science), we must discuss the relations between our flow map and the elements of NOS and Kuhn's philosophy (see Figure 1).

Although consensus about the NOS may be generally established, the meaning of the "sophisticated" Views of Nature of Science (VNOS) items remains debatable. However, the VNOS items are not to be taken in isolation. When examined holistically, they provide powerful insight into responden conceptions, especially when examining students' responses across VNOS-C items, contexts, and science-based scenarios (Schwartz, Lederman, & Abd-El-Khalick, 2012).

Table 1. *The other views about the elements of NOS*

Scientific Literacy (Zeitler & Barufaldi, 1988)	The elements of NOS		
	Skill	Attitude	Knowledge
Inter-relationship NOS (Oh, 2017)	No scientific methods, observation & inference (theory – dependence, creativity)	Social dimension & Social and Cultural effects, (theory – dependence, creativity)	Scientific knowledge, Empirical
Kuhn's Philosophy and History of Science	The seriousness of a crisis & Revolution Completion by disciplinary successors of a new paradigm	A crisis in Normal science	Revolution Completion by disciplinary successors of a new paradigm

Zeitler and Barufaldi (1988) encourage educators to use experiences of scientific enquiry, scientific attitudes, and basic scientific knowledge in teaching, all of which are integrated as scientific literacy. Therefore, it is necessary to present the NOS as a combination of these three elements in this study as well. Attitudes about science can have a significant effect on scientific literacy. In education theory, understanding of content lies in the cognitive domain, while attitudes lie in the affective domain. According to Flick (1993), there are three major dimensions of learning in science: knowledge, skills, and attitudes.

Within the field of science education, there has been sustained interest in better preparing students to engage in discourse and decisions concerning societal dilemmas and controversies, first in the area of science-technology-society (STS) instruction (Solomon & Aikenhead, 1994) and more recently in relation to the socio-scientific issues (SSI) movement (Sadler, 2011; Zeidler, Sadler, Simmons, & Howes, 2005). SSI research has traditionally focused on individual decision-making (Bencze & Alsop, 2014), aiming to develop responsible citizens capable of applying scientific knowledge and habits of mind such as skepticism, open-mindedness, critical thinking, recognition of multiple forms of inquiry, acceptance of ambiguity, and search for data-driven knowledge (Zeidler, Osborne, Erduran, Simon, & Monk, 2003). Thus, according to Oh (2017), the following terms can be used to describe the attitude, skill, and knowledge factors of science learning: **Scientific attitudes** refer to the social dimension, social and cultural changes, and subjectivity (theory-ladenness). **Scientific skills** refer not to specific scientific methods but rather to imagination and creativity, observation and inference, and subjectivity (hypothesizing). **Scientific knowledge** refers to laws and theories, and the elements of the NOS necessary to achieve wider scientific literacy (see Figure 1). In particular, subjectivity consists of hypothesizing (*skills*; AAAS, 1993) and theory-ladenness (*attitudes*; Martin, 2012).

Historical case studies: the NOS flow map for establishment of Copernicus's heliocentric hypothesis

Because Kuhn examined this episode in detail in his earlier book on the Copernican revolution (1962, pp. 139-140), he could confidently use it to support his theory of revolutions.

Cognitive conflicts

Crisis in normal science due to number of serious anomalies (the crisis of Ptolemy's geocentric model). For some time, astronomers had every reason to suppose that their attempts would be as successful as those that led to Ptolemy's model. Astronomers were invariably able to eliminate a given discrepancy by making an adjustment to Ptolemy's system of compounded circles. As time went on, however, a person looking at the net result of so many astronomers' research could observe that complexity was increasing far more rapidly than accuracy.

Kuhn's revolution begins with social and cultural pressure. The crises are regarded as serious with respect to some pressing social need. The problems with Ptolemaic geocentric astronomy were pressing with respect to the need for calendar reform in Copernicus's time, and during the Renaissance, Cosmos is a simple geometric model that Neoplatonism does not comply with the increasing number of unnatural epicycles (Chalmers, 1990, p. 113). Above all, the scientific knowledge of the Renaissance period involved reasonable explanations for obvious movements and experience. The system was nothing more than explanations appropriate to experience. <*Socio-cultural pressure and the social dimension*>

Resolution of cognitive conflict

The seriousness of a crisis deepens due to the appearance of an alternative (the appearance of Copernicus's system, an alternative for Ptolemy's system). After repeated examination of old data and lengthy contemplation, Copernicus suggested that placing the sun in the center of the universe would allow for a simpler depiction of planetary motion. Upon consideration, where else would be a better place for a sun that illuminates the universe than in the universe's center (Vigoureux, 2003, p. 86)?

Although a crisis of paradigm is realized by socio-cultural pressure, and the problem is partially solved by submission of new alternatives, new problems are introduced by a new paradigm. Disciplinary successors in a new paradigm arise as new alternatives emerge, and the old paradigm feels the severity of the crisis. In other words, study to solve new problems begins. Subjective and theory-dependent empirical data are identified as the new study direction for a new paradigm.

One of Kuhn's propositions about the NOS is the "theory-ladenness of observations." This thesis asserts that existing conceptions affect our perspective of the world around us (Loving & Cobern, 2000). In ancient Greece, Aristarchus suggested that the earth may rotate about an axis and revolve in an orbit around the sun. Almost 2000 years later, Copernicus also made this conclusion, presenting a system of the universe based on a combination of the earth's two motions about the sun to explain the retrograde motions of planets without the epicycles suggested by Ptolemy (Cohen, 1985, p. 45).

The Copernican system has more problems in an observational sense than the Ptolemaic system, because it was accepted that celestial bodies, based on Aristotle's ideas, demonstrated uniform circular motion, called "natural motion." However, the system strongly attracted disciplinary successors such as Galileo, Kepler, and Newton due to its "beauty." In other words, relative to the Neoplatonic philosophy popular at their time, which emphasized a simpler and beautiful sense (qualitatively simple and harmonious), the Ptolemaic system's explanations grew more and more complicated <*Subjective and hypothesizing* >.

Revolution by disciplinary successors of a new paradigm

The two rival systems were more or less equivalent with respect to simplicity and accord with observations of planetary positions. Nevertheless, a number of mathematically capable natural philosophers (Galileo, Kepler, and Newton) were attracted to the Copernican system. With Kepler, the Copernican revolution nearly reached “completion”; Kuhn identifies its final completion in Newton’s system (Sharrock & Read, 2002, p. 79). “Bringing together mathematicians and natural philosophers was a fundamental shift, one that involved social changes as well as intellectual ones. Over a hundred years went by before Newton fused their two approaches together in his book on gravity, making astronomy a mathematical science that aimed both to describe and to explain the cosmos” (Fara, 2009, p. 111).

“Opposition to Copernicanism did not simply collapse, but persisted, and only gradually faded away over the 150 years after the dearth of Galileo in 1642” (Sharrock & Read, 2002, p. 80). The main attraction of the Copernican hypothesis was how clearly it explained a number of features of planetary motion, which the rival Ptolemaic theory could explain only in an unattractive, artificial way.

The necessary reliance of science on empirical evidence distinguishes it from other disciplines, such as philosophy and social science. Its empirical basis is the aspect that we most easily understand. This is because we have significant concrete experience that evidence and experiments are important in science.

Although existing evidence is explained by a new theory, new evidence is also inferred and predicted. Galileo continued his studies, and in a mathematical abstraction he refuted the tower argument (which had been presented as counterevidence against the earth’s rotation) through an argument for stellar parallax (which was difficult to observe because of the great distance), based on his prediction that observations made not by the naked eye but by telescope would see stars behave identically, unlike planets. Ultimately, he presented some data supporting the heliocentric theory based on the phase changes of Venus *<Empirical Evidence>*. This example illustrates that scientific knowledge is based on empirical evidence, which is in turn based on inferred and predicted observations.

Later, based on the observations of Tycho, Kepler solved the problem of epicycles with his claim that a planet’s orbit was elliptical rather than circular. Kepler’s inference is most significant. He could not identify an elliptical orbit directly from Tycho’s data; instead, he explained Tycho’s observations by arriving at the conclusion of an elliptical orbit through an intermediate form from an initial circular orbit model.

An accurate picture of an elliptical orbit is difficult to obtain through observation. Although an accurate elliptical orbit only revolves when there is only one planet with the sun of infinite mass. Thus, abstract inference work is required. Rather than relying on empirical data from simple observations, it is absolutely necessary for scientists to use creativity in inference. This is because not only is observational data interpreted by inference, but inference forms the foundation for evaluating and predicting other observational data *<Empirical Evidence> through <Observations and Inferences>*.

The so-called “hierarchy of credibility” found in most science textbooks presents categories of scientific knowledge (i.e., observations, hypotheses, theories, laws/principles) in ascending order of credibility or certainty. Individuals often hold the simplistic, hierarchical view such lists present of the relationship between theories and laws—that is, that theories become laws as supporting evidence is accumulated over the years. It follows from this notion that scientific laws have a higher level of credibility than scientific theories.

This common belief about the relationship of theories and laws is inappropriate because, among other reasons, theories and laws are different kinds of knowledge, and one cannot develop or be transformed into the other. Laws are **statements or descriptions of relationships** among observable phenomena. Theories, by contrast, are **inferred explanations** for observable phenomena.

Usually, scientists do not formulate theories in the hope that one day they will acquire the status of "law." Scientific theories in their own right serve important roles, such as guiding investigations and generating new research problems, in addition to explaining relatively huge sets of seemingly unrelated observations in more than one field of investigation. For example, kinetic molecular theory serves to explain phenomena related to changes in physical states of matter, rates of chemical reactions, and heat and its transfer, to mention just a few.

Newton constructed the theory of gravity to explain Galileo's law of falling (based on a natural phenomenon) and Kepler's empirical law of an elliptical orbit, showing that a planet's revolution had a causal mechanism rather than a teleological cause, as suggested by Aristotle. Newton first constructed a law of gravity, then used Kepler's law to justify his theory. Therefore, laws and theories are have mutually dynamic but different roots, rather than a hierarchical order. <*Law and Theory*>**.**

The development of scientific knowledge is based on human imagination and creativity. Scientific knowledge is not simply a product of logic and rationality. There is no single "scientific method" a scientist must follow to produce scientific knowledge (AAAS, 1993; NRC, 1996; Shapin, 1996).

Individual disciplinary successors do not construct laws or theories simply through logical induction from collected data; creative work and insight are required to solve problems *<No Single Scientific Method>, <Individual Creativity>.*

Galileo's and Kepler's theories certainly enhanced Copernicus's theory. However, Copernicus's theory for comprehensive physics required more development. Newton replaced Galileo's law of circular inertia with the law of linear inertia. Of course, Newton's significant contribution is his theory of universal gravitation. With this theory, Newton could explain that Kepler's laws of planetary motion and Galileo's law of falling were correct < *theories and laws* >.

"It was Galileo's contemporary, Kepler, who contributed a major breakthrough in that direction when he discovered that each planetary orbit could be represented by a single ellipse, with the sun at one focus. This eliminated the complex system of epicycles that both Copernicus and Ptolemy had found necessary" (Chalmers, 1990, p. 100). Although the parallax-distance relation is a very simple mathematical formula, obtaining a value to use in the formula is very difficult, because the angle by which the star shifts is extremely small. It was not until the 1980s that the first parallax was measured by German astronomer Friedrich Bessel at Königsberg Observatory (now in Kaliningrad).

A new stage of normal science and its recycling: the expansion of normal science

> Galileo and Kepler certainly strengthened the case in favor of the Copernican theory. However, more developments were necessary before that theory was securely based on a comprehensive physics. Newton was able to take advantage of the work of Galileo, Kepler and others to construct that comprehensive physics. Once Newton's physics had been constituted, it was possible to apply it in detail to astronomy, fluid mechanisms and other domains. (Chalmers, 1982, p. 74)

New normal science: updating

Continuously expanded Newtonian models were applied to fluid mechanisms and other domains. Astronomers have long known that the major axis of Mercury's orbit does not remain fixed in space in relation to the stars. The major axis rotates around in the plane of the orbit. Part of this shift arises from the gravitational attraction of the other planets. When this and other effects are taken into account, there nonetheless remains a residual shift of 41 arcsec per century.

Is there perhaps an undiscovered planet, sometimes called Vulcan, orbiting within Mercury's orbit (Newtonian model's auxiliary hypothesis)? No such planet has ever been definitively observed (observation unexpected by Newtonian theory).

Recycling: retiring or revising Newton's theory

General relativity predicts motion influenced by the strong curvature of space-time close to the sun. Because the observed and predicted results of Mercury's rotation coincide to within a few percentage points, observations confirm general relativity.

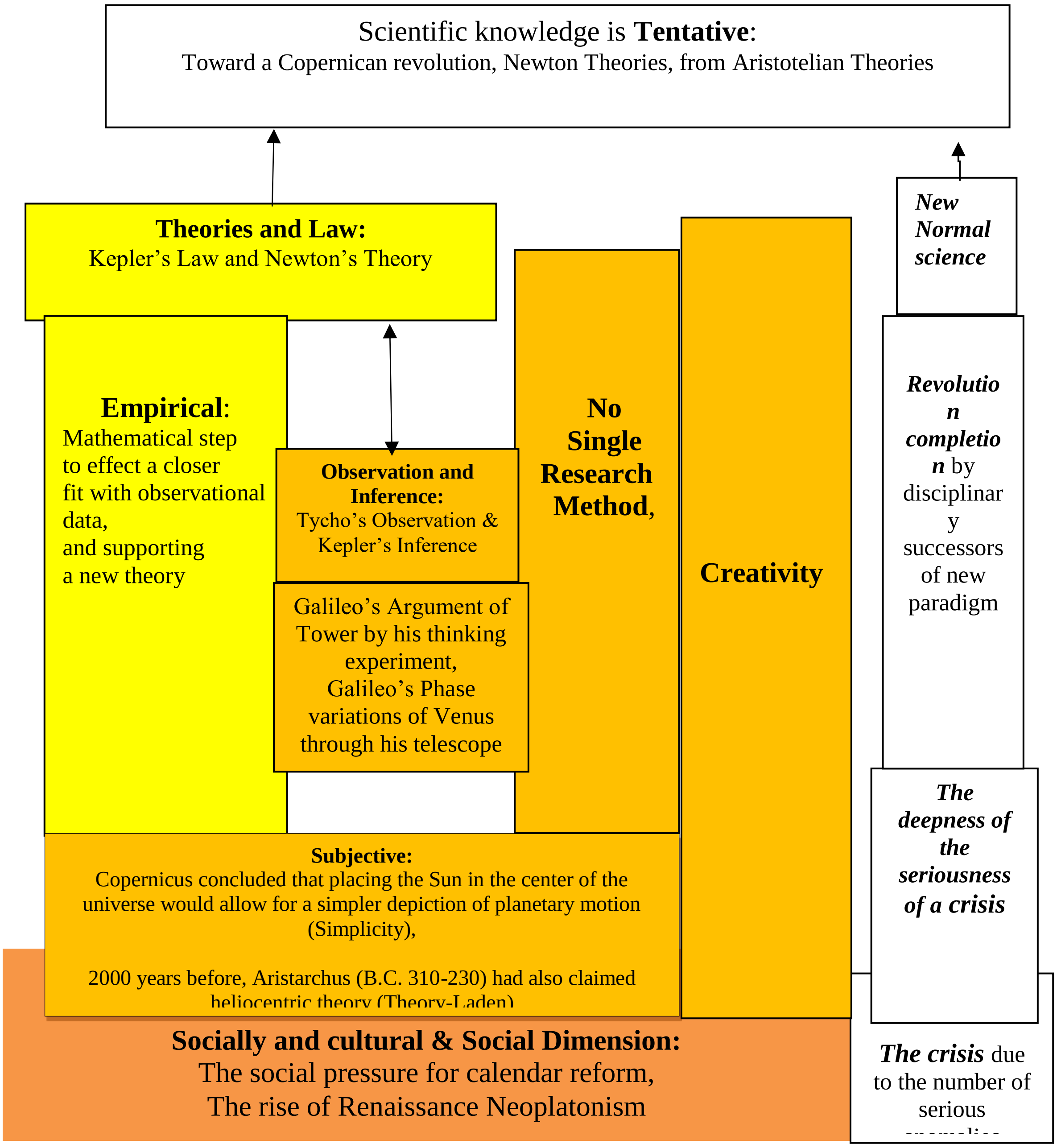


Figure 2. *The Copernican revolution: The Flow Map of the Nature of Science (NOS)*

METHOD AND PROCEDURE

Participants

The research subjects were 100 second-year pre-service elementary teachers enrolled in the Earth Science course for elementary science education in the fall term of the 2013-2014 academic year. They were selected based on their respective agreement to participate in S. N.

University of Education, located in Seoul, South Korea. The class was conducted by two professors and one Masters graduate student; two professors and one Masters graduate student conducted the research analysis. In this study, the experimental group (HOS with conceptual change model based on a developed NOS flow map; 50 students) and the HOS group without cognitive conflicts (50 students) were selected separately, with the assumption that pre-service elementary teachers' views of the NOS could not easily be changed by HOS methods alone, without cognitive conflicts.

Teaching the NOS: application of Galileo's historic investigation of sunspots with CCM based on NOS flow map

The sun was considered a symbol of perfection in traditional cosmology, but Galileo confirmed that the sun had spots, and asserted that it was not perfect. Although others had discovered these spots in the past, they were believed to be caused by the sun's moons passing in front of it, rather than spots on the sun's body itself.

> … many of these spots are seen to originate in the middle of the solar disc, and likewise many dissolve and vanish far from the edge of the sun, a necessary argument that they must be generated and dissolved. For without generation and corruption, they could appear there only by way of local motion, and they all ought to enter and leave by the very edge. (Galilei, 1967, p. 54)

Galileo asserted that sunspot groups appear to pass across the sun because the sun rotates. He based this assertion on observations of sunspot groups that he made on June 10 and June 11, 1612 (Hoskin, 1997, p. 128). Based on continuous observations, he found that the rotation period of the sun did not exceed a month (Fraknoi, Morrison, & Wolff, 1997, p. 295). Ultimately, Galileo's record of the apparent movement of sunspots proved that the sun rotates. In a famous passage from his *Dialogue Concerning the Two Chief World Systems*, Galileo states the following through the character Salviati, who serves as his mouthpiece:

> … The other observation, …, is that from the changes of shape observed in the spots, and from their apparent changes in velocity, one must infer that the spots are in contact with the sun's body… (Galilei, 1967, p. 54)

Scientists later showed that the rotation period of the sunspots differed depending on latitude, and that their maxima had an average interval of 11.1 years.

This phenomenon can be explained by the sun's magnetic field. The strong magnetic fields of the sunspots interfere with the flow of gas, by which thermal energy within the sun is delivered to the surface in currents. Due to this interference, areas with strong magnetic fields deliver less thermal energy. Therefore, areas with strong magnetic fields have a lower temperature, and are observed as dark spots (Fraknoi et al., 1997, pp. 296-297).

Sequence for use of NOS flow map: focusing on Galileo's sunspot discovery process

The class was conducted using the process by which Galileo discovered sunspots on the sun's surface and how it supported Copernicus's heliocentric hypothesis. Cognitive conflicts were resolved through reference to events in scientific history (see Oh, 2011). Although it was conducted in an orderly way by social and cultural pressure as anomalies, it was also conducted for these conflicts resolution as implicit NOS (HOS) at the first stage, and then an explicit NOS presentation (NOS flow map) at the last stage, as shown in Figure 4.

In other words, not every science process, skills instructional sequence, or scientific inquiry activity is an implicit attempt to enhance learners' conceptions of the NOS, nor is every instructional sequence in HOS an explicit attempt to achieve that end. The basic difference between implicit and explicit approaches lies in the extent to which learners are helped to grasp the conceptual tools—in this case specific aspects of the NOS—that enable them to think about and reflect on the activities in which they are engaged (Abd-El-Khalick & Lederman, 2000b).

Thus, HOS is focused on an implicit NOS approach to instruction, using cognitive conflicts inherent only in scientific history rather than suggesting the elements of the NOS. In contrast, an explicit NOS approach to instruction presents a dynamic change, with the HOS topic focused on instruction of an NOS flow map developed and suggested as a lecture tool by this study.

Pre-service elementary teachers' understanding of the NOS was explored through an explicit NOS flow map developed as an NOS instructional tool. The lessons combined cognitive conflict strategies in HOS episodes (Galileo's discovery of sunspots) with accompanying responses consisting of illustrations and questions. The experimental group's lessons were designed to include 50 minutes devoted to HOS, including conflict strategy, and 30 minutes to an explicit NOS flow map including all elements of the NOS. The HOS only group's lessons were designed to include 50 minutes only, devoted to HOS and including conflict strategy, as shown in Figure 3.

First Stage: History of Science (HOS)

Instruction in the HOS group was completed without the cognitive conflicts of the CCM.

Understanding students' preconceptions.

The teacher assumes students' preconceptions to be the Aristotelian sunspot model from HOS.

> **(Simplicio)** Aristotle first laid the basis of his argument *a priori*, showing the necessity of the inalterability of heaven by means of natural, evident, and clear principles. He afterward supported *a posteriori*, by the senses and by the traditions of the ancients. (Galilei, 1967, p. 50)
>
> **(Simplicio)** … Some say, "They are stars which, like Venus and Mercury, go about the sun in their proper orbits, and in passing under it present themselves to us as dark: and because there are many of them, they frequently happen to collect together, and then again to separate." … At the same time to maintain to incorruptibility and ingenerability of the heavens. (Galilei, 1967, p. 53)

Arousing cognitive conflict by suggesting socio-cultural pressure (finding of astonishing phenomena)

Sunspots could not be explained based on previous theories (the Aristotelian sunspot model). <Socio-cultural pressure> (generation of Cognitive Conflict by anomalies) (**Students hold Aristotelian sunspot model**)

> *Teacher:* In science history, these black spots were interpreted as shadows of planets cast by light coming from stars, with the movement of shadows caused by the orbital movement of Mercury or Mars.
>
> **(Salviati)** … it may be inferred from the same changes of shape that none of these are stars or other spherical bodies, because of all shapes only the sphere is never seen foreshortened, nor can it appear to be anything but perfectly round. So if any of the individual spots were a round body, as all stars are deemed to be, it would present the same roundness in the middle of

the sun's disc as at the extreme edge, whereas they so much foreshorten and look so thin near that extremity, and are on the other hand so broad and long toward the center … (Galilei, 1967, p. 55)

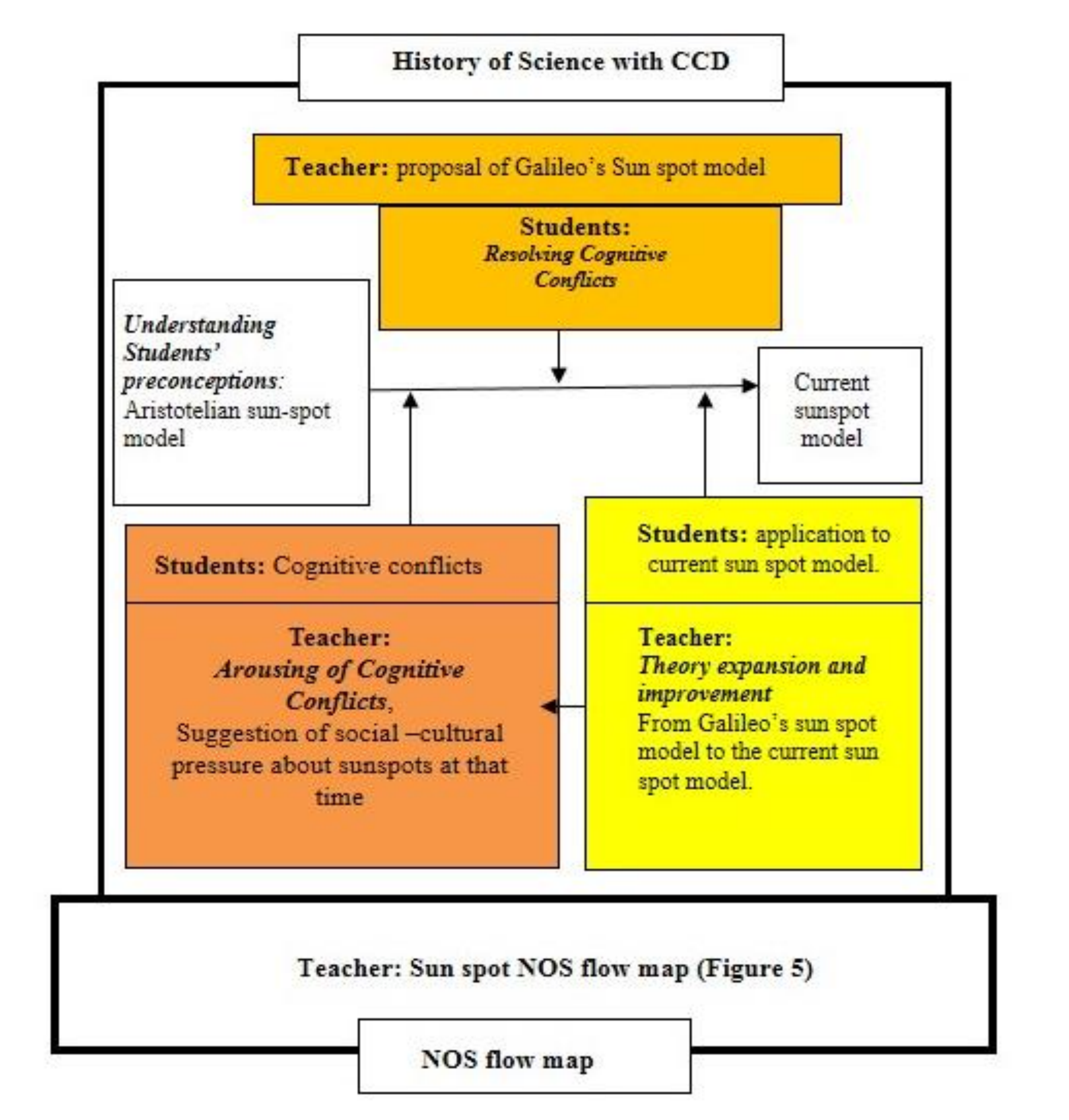


Figure 3. *Sequence of NOS instruction.*

Resolving cognitive conflict through HOS

Teacher (proposal of hypothesis): We should think that there are actual spots on the sun's surface, and their movement is caused by the rotation of the sun, as follows.

In a famous passage in *Dialogue Concerning the Two Chief World Systems*, Galileo says, through his mouthpiece Salviati:

The shapes of the spots prove the same by appearing very narrow around the sun's edge in comparison with how they look in the vicinity of the center.

> For around the center they are seen in their majesty and as they really are; but around the edge, because of the curvature of the spherical surface, they show themselves foreshortened. These diminutions of … shape, for anyone who knows how to observe them and calculate diligently, **correspond exactly to what ought to appear if the spots are contiguous to the sun**. (Galilei, 1967, p. 54)

> The students select an explanatory hypothesis through reject a hypothesis that can become existing alternative through the history of science.

Predicted and observed results expected by the chosen hypothesis

If the hypothesis that spots on the sun's surface move due to the sun's rotation is true, and if it is assumed that the sun has a crevice like Earth, and if the spots are observed in a location where the inner planet does not pass and their revolution periods are not consistent, then the spots will appear over a fixed period, moving in the direction of the sun's rotation.

> **(Salviati)** … which are conclusively proved to be produced and dissolved and to be situated next to the body of the sun and to revolve with it or in relation to it. (Galilei, 1967, p. 58)

Conclusion drawn by comparing predicted and observed results

Students conclude that the spots appeared over a fixed period. Therefore, the hypothesis that the spots on the sun's surface move due to the sun's rotation is supported: the sun rotates.

Theory expansion and improvement

> *Teacher:* Because the sun rotates in this way without exception, Copernicus's heliocentric hypothesis, asserting that the Earth is a planet that can move, is supported. Additionally, the theory that strong magnetic fields are the reason is improved.
>
> Given the fact that all celestial bodies share similar properties as Earth, all celestial bodies are imperfect, in contradiction to Aristotelian tenets. The Earth and the celestial bodies are comprised of the same material following the same laws of motion. Galileo's insight states that the fall of an apple toward earth's surface is related to the moon's orbit of the earth.

Final stage: reflection on explicit NOS flow map of sunspot discovery

Teacher:

A new flow map, using core elements of the NOS and the prerequisite conditions for a scientific revolution proposed by Kuhn (1996), was applied to the sunspot discovery process. The core NOS elements and Kuhn's (1996) conditions for scientific revolution are systematically related and correspond well to each other, as shown in figure 4.

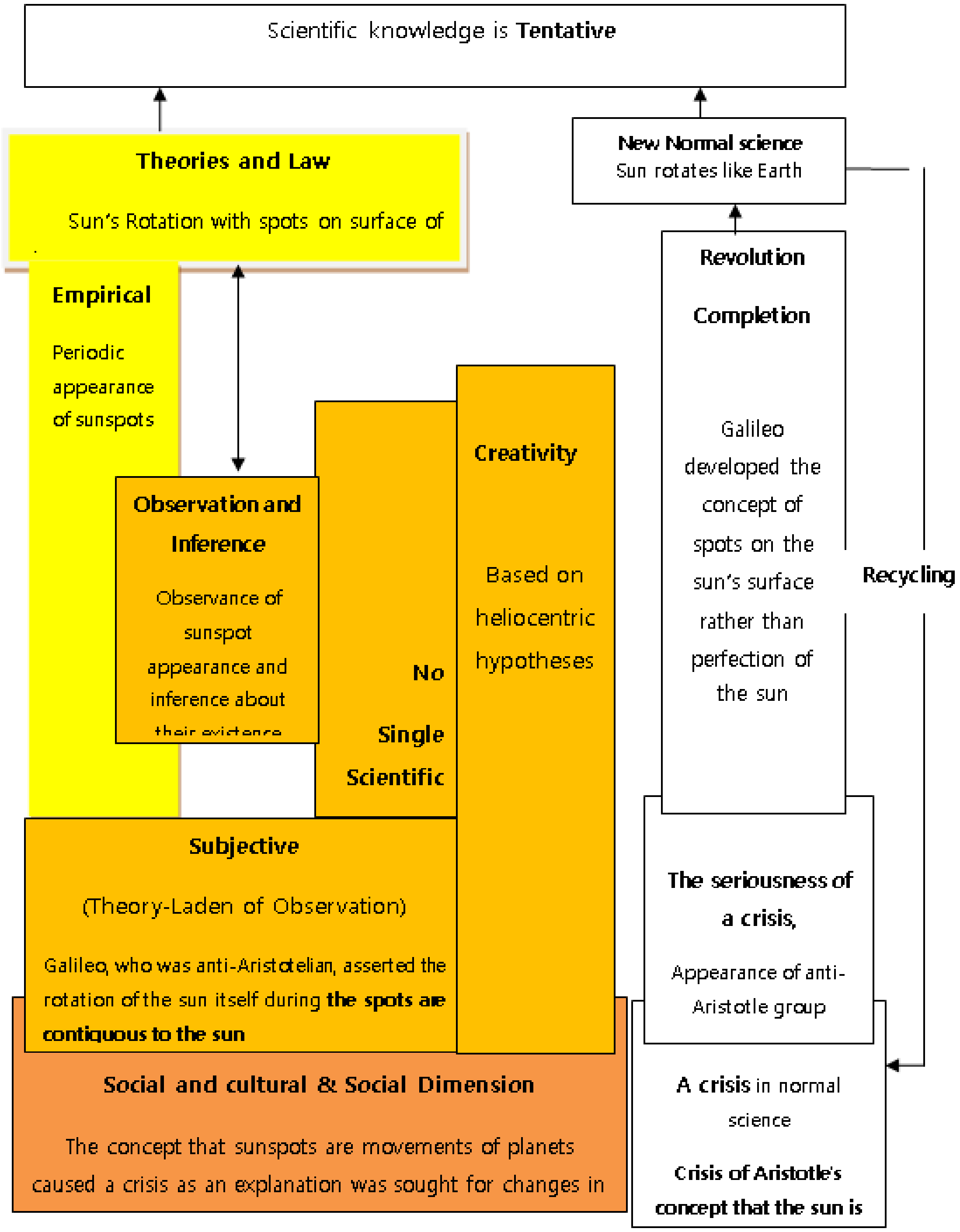


Figure 4. *NOS flow map for the sunspot discovery process.*

Test Instruments

VNOS has been repeatedly emphasized in many major science education reform efforts (Clough, 2006; McComas, 2008; McComas, Clough, & Almazroa, 1998; Deng, Chen, Tsai, & Chai, 2011), and it has been suggested as a vital component of scientific literacy (Abd-El-Khalick & Lederman, 2000a; Lederman, 2007; Millar & Osborne, 1998). Driver, Leach, Millar, and Scott (1996) delineated the importance of VNOS by explicating five potential benefits when students express sophisticated VNOS. Specifically, VNOS helps students to (1) understand the process of science, (2) make informed decisions on socio-scientific issues, (3) appreciate science as a pivotal element of contemporary culture, (4) be more aware of the norms of the scientific community, and (5) learn science content with more depth.

Lederman (2007) specifies the definition of the NOS and what key aspects it should include. He concludes that K-12 students do not possess “adequate” views of the NOS. Their misconceptions of the NOS can be attributed to the ineffectiveness of curricular or instructional approaches, teachers’ “inadequate” VNOS, and other situational variables, such as instructional behaviors, activities, and decisions implemented within the classroom context (Deng et al., 2011).

The VNOS-C probes learners’ ideas about different forms of investigation through more comprehensive questioning. This study employed a questionnaire used by Choi et al. (2009) (which included VNOS-C items 1, 2, 3, 4, 5, 8, 9, and 10 and VNOS-B item 6) to test NOS instruction using HOS. This questionnaire incorporates open-ended questions related to the definition of science, the empirical nature of scientific knowledge, the temporality of scientific knowledge, the scientific method, characteristics of scientific inference, the theory-dependence of observation, the social structure of scientific knowledge, and creative characteristics of science.

Selection of experimental group and HOS only group without CCM

Implicit NOS group using HOS only without CCM

Galileo’s process for discovery of sunspots was selected as the HOS episode for study. Scientific knowledge has a history that develops through the thought and studies of scientists over long periods of time.

Explicit NOS experimental group using HOS with CCM and NOS flow map

After having the history science group with CCM, explicitly, using the NOS flow Map including elements of nature of science, classes were carried out in order.

Data collection

After selecting the two groups in the fall semester of the 2013-2014 academic year, pre-testing (VNOS-C) on the NOS was conducted. Then, after each group’s classes were completed, the same test was conducted as a post-test.

Data analysis

The results of the test (VNOS-C) on the NOS were analyzed by dividing them into the proposed classic viewpoint (naive views) and the modern viewpoint (informed views). The elements and analysis frameworks of science are shown in Table 2. The analysis was conducted by two experts in science education, and was repeated until inter-rater reliability reached 90%. For each group, Wilcoxon verification of the pre- and post-test was conducted using SPSS 18.0™.

Table 2. *Analysis frameworks of illustrative examples for responses about the Nature of Science (VNOS –C)*

Aspect of NOS	More Naive views	More Informed views
The definition of Science	Science is absolute and **objective**.	Science depends on observations, but I don't think that science is absolute and objective by observable facts.
Empirical Nature of Science	An experiment is a sequence of steps performed to prove **only existing theories**	An experiment is a sequence of steps performed to prove proposed hypothesis and discover a new fact
The diversity Of Scientific Method	The development of scientific knowledge can **only be attained through precise experiments**	Experiments are not always crucial.. Einstein's theory of special relativity … cannot be directly tested experimentally.
Scientific knowledge as tentative	Theories in science **should be not subject to change** with interpretation of that evidence, because of disorder, and their objectivity	Everything, specially theories in science is subject to change with new evidence and interpretation of that evidence
Difference between Theory and law	Laws stated as theories and eventually became laws after repeated and proven demonstration.	A scientific law describes quantitative relationships between phenomena. Scientific theories propose new explanatory models for the world.
Difference between Knowledge and view	Scientific knowledge is **true**, Views are individual explanatory tools	Scientific knowledge are proved, but views are their opinions and thoughts
The theory-dependence of observation	Scientists reach different conclusions, because I think that **their data are not fluent and fault**, but scientists are very objective.	Both conclusions are possible because of different explanations based on their own education and background.
Social and Cultural Embeddedness	Scientific knowledge is **universal** and does not be changed by cultures and society.	All factors in society and the culture influence the acceptance of scientific ideas.
Creative and imaginative	A scientist only used imagination in collecting data … But there is **no creativity** after scientist has to be objective.	Creative and imagination are essential for entire procedure of the formulation of novel ideas … to explain why the results were observed.

Table 3. *The effectiveness about instruction of NOS about the experiment group (History of science with CCD based on NOS flow map) through VNOS-C test*

Elements of NOS	Test	The experiment group (History of science with CCD based on NOS flow map)		The History of Science group without cognitive conflicts	
		More Informed views (% Changed)	Significance probability	More Informed views (% Changed)	Significance probability
The definition of Science	*Pre*	7	*p*=.000 *	45 (+56)	*p*=.000 *
	Post	37 (+60)		10	
Empirical Nature of Science	*Pre*	17	*p=.000* *	25 (+30)	*p*=.000 *
	Post	40 (+46)		38	
The diversity Of Scientific Method	*Pre*	6	*p=.000* *	39 (+2)	*p=.000* *
	Post	33 (+54)		47	
Scientific knowledge as tentative	*Pre*	42	*p=.000* *	48 (+4)	*p=.015* *
	Post	50 (+16)		34	
Difference between Theory and law	*Pre*	14	*p=.000* *	32 (-4)	*p=.000* *
	Post	48 (+68)		46	
Difference between Knowledge and view	*Pre*	40	*p=.000* *	49 (+2)	*p=.000* *
	Post	45 (+10)		38	
The theory-dependence of observation	*Pre*	44	*p=.000* *	34 (-8)	*p=.000* *
	Post	50 (+12)		7	
Social and Cultural Embeddedness	*Pre*	8	*p=.000* *	17 (+20)	*p=.000* *
	Post	34 (+56)		8	
Creativity	*Pre*	6	*p=.000* *		
	Post	35 (+58)			

Table 4. *The effectiveness about instruction of NOS about the History of Science group without cognitive conflicts through VNOS-C test*

Elements of NOS	Test	More Informed views (% Changed)	Significance probability
The definition of Science	*Pre*	17	*p*=.000*
	Post	45 (+56)	
Empirical Nature of Science	*Pre*	10	*p*=.000*
	Post	25 (+30)	
The diversity Of Scientific Method	*Pre*	38	*p*=.000*
	Post	39 (+2)	
Scientific knowledge as tentative	*Pre*	47	*p=.000**
	Post	48 (+4)	
Difference between Theory and law	*Pre*	34	*p=.015**
	Post	32 (-4)	
Difference between Knowledge and view	*Pre*	46	*p=.000**
	Post	49 (+2)	
The theory- dependence of observation	*Pre*	38	*p=.000**
	Post	34 (-8)	
Social and Cultural Embeddedness	*Pre*	7	*p=.000**
	Post	17 (+20)	
Creativity	*Pre*	8	*p=.000**
	Post	8 (+0)	

RESULTS

Among the VNOS-C question categories, the experimental group scored lowest in "diversity of scientific method" in both the pre- and post-test. The HOS only group scored lowest in the "creativity" category. The "social and cultural embeddedness" category received relatively high responses. The highest scores were in "tentativeness of scientific knowledge" and "theory-dependence of observation" for both groups.

The Wilcoxon verification results of the pre- and post-test, which examine the effectiveness of NOS in both the experimental group and the HOS only group, are shown in Tables 3 and 4

The explicit NOS experimental group utilized HOS instruction with cognitive conflicts involving social and cultural pressure, based on the NOS flow map.

The five most frequent and high responses among pre-service teachers are presented below.

Students A, B, C, and F, who showed change in the "tentativeness of scientific knowledge" category, provided responses similar to the following:

> *Pre-test:* Science theories come to develop gradually along with social development. But, since science is objective, the basis is difficult to change.
>
> *Post-test:* Science starts from hypotheses. So, if society changes, the hypotheses change. Naturally, scientific theories are tentative.

Example responses of students A, B, C, and F, who also showed change in the "diversity of scientific method" category, were as follows:

Pre-test: Experiments are surely necessary. That is because science is proved by experiments different from other studies.

Post-test: Though experiments are necessary, theories can initially be like the theory of relativity in modern science. In such cases, thought experiments may be necessary rather than direct experiments. Plus, in case of paleontology, revival by experiment is impossible.

Responses of teachers A, C, and D, who showed change in the relatively high-scoring “creativity” category, were similar to the following:

Pre-test: Creativity is necessary only in the course of collecting data, because science is objective. Hence, the viewpoints of individuals should not intervene in other processes.

Post-test: Creativity is necessary in all processes, because scientific theories are tentative and the work of scientists does not go into predetermined ways.

Additionally, the responses of teachers A, B, C, D, and F, who showed change in the “social and cultural embeddedness” category, were similar to the following:

Pre-test: Science theories are universal, so if they fall under the social and cultural influences of different times and places, disturbances will be raised.

Post-test: Social and cultural values cannot help but intervene. The foundation of all science is to realize the value of influence from the societies and cultures affiliated with it.

The following results focus on student A’s responses, which were common examples.

It was confirmed that the influence and pressure of the scientists’ culture and society (+56% change) influenced subjectivity (+12%, but initial score was almost 88%), as well as observation and inference along with individual creativity (+58%), which comprise the scientists’ own scientific activity.

Due to these influences, the empirical data (+46%), or scientific products, that are obtained through observation and inference (+58%) by various scientific methods (+54%) rather than a single tool such as induction, compose and support scientific theories and rules (+68%). When socio-cultural influences change, scientists’ subjective values also change, so the theories and rules fundamentally change on the basis of empirical material attained by theory-dependent scientific activity. Therefore, scientific knowledge is tentative (+16%, but initial score was almost 84%).

“Scientism” appeared commonly in the responses of the HOS only group.

The socio-cultural influence and pressure (+20) phase of cognitive conflict—that is, the phase of dissatisfaction with the existing conception—was omitted during instruction in the NOS.

Scientific knowledge is objective, so according to scientists’ objective scientific activity (−8% change, but initial score was 76%), the empirical data (+30%), obtained using the scientific method (+2%) that is universally recognized rather than diverse, support and discover theories and rules (−4%). Because empirical data are collected objectively rather than subjectively and accumulate gradually (based on the perspective that fundamental theories and rules are elaborated on and evolve little by little, progressing rather than changing), scientific knowledge is tentative (+4%, but initial score was almost 94%).

Creative inference and observation, influence scientific activity only in collection of data, rather than affecting all scientific inquiry activity; creativity is not used in the process of searching for theories and rules (+0%).

Because there was no phase of cognitive conflict or dissatisfaction in the HOS-only group's instruction, it is confirmed that conceptual change regarding the NOS is difficult in this condition. Preservice teachers in the HOS group without cognitive conflicts did not appropriately understand "social-cultural embeddedness."

The HOS without cognitive conflicts group believed that although social and cultural value is needed initially, value should become universal in the end. However, the experimental group believed that because social and cultural value changes according to period, it is the driving force of change in scientific theories.

To explicitly make clear that creativity is used in all stages of scientific investigation, a viewpoint of modern scientific philosophy, it is necessary to show that creativity is necessary and more important than inductive reasoning in each stage.

DISCUSSION

In NOS instruction, because the elements of the NOS are linked, implicit classes using HOS only are limited. This study explicitly used HOS with CCM based on an NOS flow map we developed, targeting change in VNOS among pre-service elementary teachers. The study observed large changes when comparing questionnaires from before (pre-test) and after (post-test) NOS instruction in the experimental group, relatively different from the classes that incorporated HOS only, without cognitive conflicts involving social and cultural pressure.

In addition, the elements of the NOS are not independent but interconnected (Bartholomew & Osborne, 2004; Schwartz et al., 2012). Notably, social and cultural value is linked with the theory-dependence of observation, subjectivity, deductive characteristics, and finally tentativeness.

We emphasized that value is linked with creativity in the first stage of instruction. First, we can recognize that subjectivity and creativity, like the theory-dependence of observation, are influenced most by social-cultural embeddedness. Unlike the HOS-only group, which demonstrated low effects, the instruction was very effective in the experimental group. Second, the general perception of the HOS-only group was that most scientists use creative imagination only in data collection or establishment of hypotheses. On the other hand, the experimental group perceived that scientists use creativity in all stages of scientific inquiry. Third, subjectivity is connected with the theory-dependence of observation through deductive characteristics, and ultimately with tentativeness. In the case of the HOS-only group that were not introduced to cognitive conflicts involving social and cultural pressure, little change was seen in perspective on the NOS element of tentativeness of scientific knowledge.

CONCLUSION

It is valuable to introduce students at the elementary level to some ideas developed by Kuhn (Eflin et al., 1999; Rea-Ramirez et al., 2008). Thus, we developed a flow map for key aspects of the NOS based on Kuhn's concept of constructivism, which was applied well to Galileo's discovery of sunspots, a main events in the history of astronomical science, as a historical case study.

First, many of the ideas embedded in any understanding of the NOS are difficult to present as clearly teachable propositions. In particular, it should be known that subjectivity and creativity are most influenced by the theory-dependence of observation and social and cultural embeddedness. Hence, explicit educational strategies are necessary that present the elements of the NOS as connected in a holistic manner rather as separate entities, because responses are analyzed holistically, seeking connections and consistencies (Lederman et al., 2002; Schwartz et al., 2012, p. 689).

Second, we suggest the use of an explicit NOS flow map to teach the key aspects of the NOS as a historical case study, with a good case being the Copernican Revolution, one of the main events in the history of astronomical science.

Third, our explicit NOS flow maps incorporate the instructional sequences of the NOS, HOS, SCK, and POS with the CCM. However, initially, we present a strategy that begins with the most important core aspects of the NOS, then introduces supportive SCK and HOS to explain these aspects through cognitive learning strategies (CCM). The concepts are presented explicitly and reflectively, providing a means for teachers to help students reconstruct their initial views of the NOS toward the target views.

A comparison of responses to reviews of NOS pre-test studies using the explicit NOS flow map containing general terms showed high levels of agreement about the tentativeness, subjectivity, and creativity of scientific knowledge using concrete examples from “Galileo’s explanations of sunspots.” These findings indicate that students showed change in their understanding of NOS approaching more modern views. For the NOS flow maps including HOS, SCK, and POS, the recommended instructional sequence begins with social and cultural pressure (cognitive conflicts) and progresses to revolution (resolution of cognitive conflicts).

Pre-service elementary teachers’ understanding of the NOS was explored through an explicit NOS flow map developed as an NOS instructional tool. The instructions involved a combination of cognitive conflict strategies in HOS episodes (Galileo’s discovery of sunspots) with accompanying responses consisting of illustrations and questions. The activity was designed to spend 50 minutes on HOS including conflict strategy, and 30 minutes on the explicit NOS flow map including all elements of the NOS.

Findings indicated that students showed change toward more modern views of the NOS. They demonstrated understanding of the tentativeness of scientific knowledge based on supporting empirical data gathered through observed and imagined scientific activities with creativity and the effect of social and cultural pressure.

HOS knowledge should be taught in our science teacher programs. Some knowledge of HOS for the NOS can be as useful to students as to working scientists. Although this study did not demonstrate that HOS played a dual role in significantly increasing student scores for both the NOS and SCK, it is clear that HOS provides instructional resources for science teaching if it is explicitly contextualized into domain-specific content. A science teacher of science must also bring to the classroom the attitude and worldview of a scientist, because experiencing the processes of science alone is not sufficient. To achieve this, a basic understanding of Kuhn’s philosophy of science is necessary. Therefore, an explicit NOS flow map incorporating cognitive conflict strategies could be a promising NOS method and an explicit and reflective tool to enhance science teaching and learning.

ACKNOWLEDGEMENTS

This work was supported by the Foundation of Hanyang University of Korea (HY-201500000002899).

REFERENCES

Abd-El-Khalick, F., & Akerson, V. L. (2004). Learning about nature of science as conceptual change: Factors that mediate the development of preservice elementary teachers' views of nature of science. *Science Education, 88*(5), 785–610.

Abd-El-Khalick, F., & Lederman, N. G. (2000a). Improving science teachers' conceptions of the nature of science: A critical review of the literature. *International Journal of Science Education, 22*(7), 665–701.

Abd-El-Khalick, F., & Lederman, N. G. (2000b). The influence of history of science courses on students' views of nature of science. *Journal of Research in Science teaching, 37,* 1057–1095.

Akerson, V. L., Morrison, J., & McDuffie, A. R. (2005). One course is not enough: Preservice elementary teachers' retention of improved views of nature of science. *Journal of Research in Science Teaching, 43*(2), 194–213.

American Association for the Advancement of Science. (AAAS) (1993). *Benchmarks for science literacy: A Project 2061 report*. New York: Oxford University Press.

Bartholomew, H., and Osborne, J. (2004). Teaching students "ideas about science" Five dimensions of effective practice. *Science Education, 88*(5), 655–682.

Bakırcı, H., Çalık,M. and Çepni, S (2017). THE EFFECT OF THE COMMON KNOWLEDGE CONSTRUCTION MODEL-ORIENTED EDUCATION ON SIXTH GRADE STUDENTS' VIEWS ON THE NATURE OF SCIENCE, *Journal of Baltic Science Education, 16*(1), 43-55.

Bell, R. L., Matkins, J. J. M., and Gansneder, B. M. (2011). Impacts of Contextual and Explicit Instruction on Preservice Elementary Teachers' Understandings of the nature of science. *Journal of Research in Science Teaching, 48*(4), 414–436.

Bencze, L., & Alsop, S. (2014). Activism! Toward a more radical science and technology education. In Activist science and technology education (pp. 1–20). Dordrecht: Springer Netherlands.

Brown, H. I. (1977). *Perception, theory and commitment: The new philosophy of science*. Chicago: The University of Chicago Press. Cawthron, F. R. & Rowell, J. A. (1978). Epistemology and science education, *Studies in Science Education, 7*, 279–304.

Chalmers, A. F. (1982). *What is this thing called science? (2nd edition).* Miton Keynes: Open University Press. Chalmers, A. F. (1999). *What is this thing called science? (3rd.edition).* Cambridge: Hackett Publishing Company, Lnc.

Clough, M. P. (2006). Learners' responses to the demands of conceptual change: considerations for effective nature of science instruction. *Science Education, 15*, 463–494.

Cohen, I. B. (1985). *The Birth of a New Physics: Revised and Updated*. New York: W. W. Norton & Company, Inc.

Colagrande E.A., Martorano, S.A.A., & Arroio, A. (2016). Assessment on How Pre-Service Science Teachers View the Nature of Science. *Journal of Turkish Science Education, 13*(4), 293-307

Deng, F., Chen, D.-T., Tsai, C.-C., & Chai, C. S. (2011). Students' views of the nature of science: A critical review of research. *Science Education, 95*, 961–999.

Driver, R., Leach, J., Millar, R., & Scott, P. (1996). *Young people's image of science*. Buckingham, England: Open University Press.

Duschl, R. A. (1990). *Restructuring science education*. New York: Teachers College Press.

Eflin, J. T., Glennan, S., & Reisch, G. (1999). The nature of science: A perspective from the philosophy of science. *Journal of Research in Science Teaching, 36*(1), 107–116.

Fara, P. (2009). *Science: a Four thousand year history*. Oxford: Oxford University Press.

Fraknoi, A., Morrison, D. & Wolff, S. (1997). *Voyages through the universe*. New York: Saunders College Publishing.
Galilei, G. (1967). *Dialogue concerning the Two Chief World Systems. Translated by Stillman Drake*. Berkeley and Los Angeles: University of California Press.
Gess-Newsome, J. (1999). Teachers' knowledge and beliefs about subject matter and its impact on instruction. In J. Gess-Newsome & N. G. Lederman (Eds.). *Examining pedagogical content knowledge: The construct and its implications for science education* (pp. 51–94). The Netherlands: Kluwer Academic Publishers.
Giere, R. N. (1999). *Science without laws*. Chicago: University of Chicago Press
Hewson, P. W., Beeth, M. E., & Thorley, N. R. (1998). Teaching for conceptual change. In B. J. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (pp. 199–218). Dordrecht: Kluwer.
Hoskin, M. (1997). *The Cambridge illustrated history of astronomy*. Cambridge: Cambridge University Press.
Hull, D. L. (1998). *Science as a process: an evolutionary account of the social and conceptual development of science*. Chicago: University of Chicago Press.
Kuhn, T. S. (1962). *The structure of scientific revolution (1st edition)*, Chicago, IL: The University of Chicago Press.
Kuhn, T. S. (1977). *The essential tension*. Chicago: University of Chicago Press.
Kuhn, T. S. (1996). *The structure of scientific revolutions (3rd Edition)*, Chicago, IL: The University of Chicago Press.
Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of NOS questionnaire (VNOS): Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching*, *39*, 497–521.
Lederman, N. G. (2007). Nature of science: Past, present, and future. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education*. Mahwah, NJ: Erlbaum.

Loving, C. C. & Cobern, W. W. (2000). Invoking Thomas Kuhn: What Citation Analysis Reveals about Science Education. *Science & Education*, *9*, 187–206.
Martin, D. J. (2012). *Elementary Science Methods: A Constructivist Approach (6th Edition).* Canada: Wadsworth, Cengage Learning
McComas, W. F., Clough, M. P., & Almazroa, H. (1998). The role and character of the nature of science in science education. *Science & Education, 7*, 511 – 532.
Millar, R., & Osborne, J. (1998). *Beyond 2000: Science education for the future*. London: King's College.
Morrison, J. A., Raab, F., & Ingram, D. (2009). Factors influencing elementary and secondary teachers' views on the nature of science. *Journal of Research in Science Teaching, 46*(4), 384–403.
National Research Council (NRC) (1996). *National science education standards. Washington*. DC: National Academic Press.
Niaz, M. & Maza, A. (2011). *Nature of science in general chemistry textbooks*. New York: Springer.
Oh, J.-Y. (2017). Suggesting a NOS Map for Nature of Science for Science Education Instruction. *Eurasia Journal of Mathematics Science and Technology Education, 13*(5), 1461-1483.
Oh, J.-Y., Lee, H, & Lee, S. (2017). Using the Lakatosian Conflict Map for Conceptual Change of Pre-service Elementary Teachers about the Seasons. *Research in science & technological education*, *35*(1), 17-41
Pintrich, P. R., Marx, R.W., and Boyle, R.A. (1993). Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. Review of Educational Research, 63, 167-199.

Posner, G., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: toward a theory of conceptual change. *Science Education, 66*(2), 211–277.

Rea-Ramirez, M. A., Clement, J., and Nŭňez-Oviedo (2008). An instructional Model Derived from Model Construction and Criticism Theory. In J. J. Clement, and M. A. Rea-Ramirez (Eds.), *Model-based learning and instruction in science*. Springer

Sadler, T. D. (2011). *Socio-scientific issues in the classroom. Teaching, learning and research.* Germany: Springer.

Shapin, S. (1996). *The Scientific Revolution*. Chicago: The University of Chicago Press.

Schwartz, R. S., Lederman, N., & Abd-El-Khalick, F. (2012). A Series of Misrepresentations: A Response to Allchin's Whole Approach to Assessing Nature of Science Understandings to science context. *Science Education, 96*(4), 685 – 692.

Sismondo, S. (2004). Pharmaceutical maneuvers(Review), Social Studies of Science, 34(2), 149-159.

Sharrock, W. & Read, R. (2002). *KUHN: Philosopher of scientific revolution. Malden*. MA: Polity Press c/o Blackwell Publishing Ltd.

Solomon, J., Duveen, J., Scott, L., & McCarthy, S. (1992). Teaching about the Nature of Science through history: Action research in the classroom. *Journal of Research in Science Teaching*, 29(4), 409–421.

Solomon, J., & Aikenhead, G. S. (1994*). STS education: international perspectives on reform. Ways of knowing science series.* New York: Teachers College Press.

Tao, P. K. (2003). Eliciting and developing junior secondary students' understanding of the nature of science through a peer collaboration instruction in science stories. *International Journal of Science Education, 24*(4), 357–368.

Torres, J., Moutinho, S., & Vasconcelos, C. (2015). Nature of science, scientific and geoscience models: Examining students' and teachers' views. Journal of Turkish Science Education, 12(4), 3-21.

Tyson, L. M., Venville, G. J., Harrison, A. G., & Treagust, D. F. (1997). A multidimensional framework for interpreting conceptual change events in the classroom. *Science Education, 81*(4), 387 – 404.

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, 357–377.

Zohar, A., & Aharon-Kravetsky, S. (2005). Exploring the Effects of Cognitive Conflict and Direct Teaching for Students of Different Academic Levels. *Journal of Research in Science Teaching, 42,* 829-855.

Vigoureux, J. M. (2003*). Les pommes de Newton. Paris: Albin Michel S. A.*, (Trans. Hee-Jung Lee, (2005), Newton's Apple, NuRim book (Seoul).

Zeidler, D. L., Osborne, J., Erduran, S., Simon, S., & Monk, M. (2003). The role of argument during discourse about socioscientific issues. In D. L. Zeidler (Ed.), *The role of Moral Reasoning on Socioscientific Issues and Discourse in Science Education* (pp. 97–116). Netherlands: Kluwer Academic Publishers.

TÜRK FEN EĞİTİMİ DERGİSİ
Yıl 15, Sayı 3, Eylül 2018

Journal of
TURKISH SCIENCE EDUCATION
Volume 15, Issue 3, September 2018

http://www.tused.org

The Effects of Educational Game-Integrated Group Research Method on Academic Achievement, Attitude towards School, and Retention of Knowledge in Teaching Regulatory System

Emre YILDIZ[1], Ümit ŞİMŞEK[2], Hacer AĞDAŞ[3]

[1] Researcher Assistant Atatürk University, Erzurum-TURKEY, ORCID ID: 0000-0001-6396-9183
[2] Prof. Dr. Atatürk University, Erzurum-TURKEY
[3]Science Teacher the Ministry of National Education, Gümüşhane-TURKEY

Received: 29.07.2017 **Revised:** 22.06.2018 **Accepted:** 18.08.2018

The original language of article is English (v.15, n.3, September 2018, pp.91-105, doi: 10.12973/tused.10239a)

ABSTRACT

The purpose of this research was to find out the effects of educational game-integrated group research method of "regulatory system" issue in 7th grade on students' academic achievement, attitudes towards schools, and retention of knowledge. The sample of this study consisted of a total of 54 students in two intact groups at 7th grade students in a middle school in the 2015-2016 academic years. One of these groups was assigned as an experimental group with the educational game-integrated group research method (n=27) and the other was assigned as control group with traditional teaching design (n=27). The experimental and control groups were randomly attributed. Within pretest-posttest control group quasi-experimental design, data were collected via Prior Knowledge Test (PKT), Academic Achievement Test and Attitude towards School Scale (ATSS). The data were analyzed via descriptive statistics and independent group t-test. The experimental group indicated significantly higher academic achievement, more positive attitudes towards school scores and higher permanent learning levels in comparison to the control group.

Keywords: Academic achievement, Attitude towards school, Cooperative learning, Educational games, Retention of knowledge.

INTRODUCTION

In our age witnessing rapid changes in science and technology, individuals can keep up with the times only if they have a quality development (MEB, 2006; Şimşek, 2007; Çavuş, Kulak, Berk & Öztuna-Kaplan, 2011; Çepni, 2011; Bayat, Kılıçaslan & Şentürk, 2014). Making individuals competent in understanding the current science and technology is only possible with a good science education.

A good science education depends on methods and techniques that can provide students scientific thinking skill, enable them to do research in this field, have a positive effect on their attitudes towards science lessons, move them away from rote learning, and provide real learning through concretizing the knowledge (Bozkurt & Olgun, 2005; Gök,

Corresponding author e-mail: emre.yildiz@atauni.edu.tr © ISSN:1304-6020

Doğan, Doymuş & Karaçöp, 2009; Koç, Şimşek & Fırat, 2013). Such methods and techniques exist in practices involving active learning.

In active learning, students get more effective outcomes in terms of academic and social skills by acquiring knowledge through thinking, questioning, experiencing, and actively participating in learning process via their own experiences (Akar, 2012; Çalışkan 2005). Using these methods and techniques facilitate learning by increasing the understandability of abstract and complex subjects and thus contribute to the realization of the aims of science lessons (Sökmen et al., 1997; Uzuntiryaki, Çakır & Geban, 2001; Rollnick et al., 2002; Bayat, Kılıçaslan & Şentürk, 2014). In these methods and techniques, students actively participate in learning process and learn via their own experiences.

Cooperative learning model, which is part of active learning, is a widely preferred model with its many methods and techniques (Siegel, 2005; Doymus, Karacop & Simsek, 2010). Cooperative learning model is a model in which small heterogeneous groups are formed out of students inside and outside the classroom based on a common goal, and students are be responsible for learning of each other and play an active role in learning environment (Açıkgöz, 1992; Hennessy & Evans 2006; Koç, Şimşek & Fırat, 2013; Okur Akçay & Doymuş, 2014).

Motivation levels, critical thinking, problem-solving, cooperation, and verbal communication skills of students in addition to positive views regarding themselves and their friends are improved in the cooperative learning model in which individuals having various skills, interests, needs, social skills, and learning styles are brought together, given a chance to work together, and required to participate in learning environment actively (Christison, 1990; Koç, 2014; Genç & Şahin, 2015).

It is reported that the cooperative learning method contributes to improve academic achievement and social skills of students (Hsiung, 2010; Carpenter, 2003; Johnson & Johnson, 1999; Önder & Sılay, 2015). Students achieve academic development through the active learning environment set in the classes where the cooperative learning model is implemented which is motivating and exploratory, allows students to defend their ideas, encourages them to work together and win together rather than triggering them to compete with each other, and prevents teachers from being regarded as the only source of information (Şimşek, 2007; Önder & Sılay, 2015; Leikin & Zaslavsky 1997; Cooper et al., 1984; Nelson Legall 1992). Through cooperative learning, students have opportunity to do research by working together, make trials, and improve some of their social skills such as expressing one's opinions, listening to each other, discussing with others, and making a shared decision on a specific issue (Genç & Şahin, 2015).

Another active learning activity employed in the present study is the educational games method. For students, the meaning of games is not only having a good time but also making important contributions to learning and creativity (Adıgüzel, 2010; Kaya & Elgün, 2015). An educational game refers to an active learning process which is conducted with or without specific rules and for or not for a specific goal, to help students in physical, cognitive, affective, psycho-motor, and social development and to help students eagerly participate (Dönmez, 1999). Games are one of the most important components of educational development for children where they express their views and establish an interaction with their environment (Şaşmaz Ören & Erduran-Avcı, 2004; Karamustafaoğlu & Kaya, 2013).

Educational games provide students social skills such as collaboration, cooperation, sharing, respecting to thoughts of others, obeying to the rules, protecting individual rights and freedoms, and establishing friendship relations in addition to improve their levels of motivation, creativity, critical thinking, problem-solving, self-confidence, and attitude towards lessons and school (Coşkun, Akarsu & Karaiper, 2012; Savaş & Gülüm, 2014; Karamustafaoğlu & Kaya, 2013; Önen, Demir & Şahin, 2012; Bayırtepe & Tüzün, 2007).

Since the "regulatory system" issue in 7th grade science curriculum involves a lot of abstract concepts, it is quite difficult for students to achieve active learning instead of memorizing. Therefore, the two active learning activities implemented cooperative learning model as the group research method and educational games method were implemented in the present study in an integrated way so that the students could actively learn the "regulatory system" issue containing a lot of abstract concepts instead of memorizing and achieving affective, social, and psychological development while learning.

The present study was conducted to explore the effects of teaching the "regulatory system" issue which is covered in the 7th grade science course through the educational game-integrated group research method on academic achievement and attitudes towards school as well as the retention of knowledge.

This research seeks an answer to the following question: "Does the teaching through educational game-integrated group research method for 'regulatory system' issue covered in the 7th grade science course have any effect on academic achievement and attitudes towards school as well as the retention of knowledge?" In this regard, an attempt was made to answer the below-mentioned sub-problems:

1. Is there any significant difference in academic achievement between the students subjected to the educational game-integrated group research method and those subjected to program-based learning?
2. Is there any significant difference in attitudes towards school between the students subjected to the educational game-integrated group research method and those subjected to program-based learning?
3. Is there any significant difference in the retention of knowledge between the students subjected to the educational game-integrated group research method and those subjected to program-based learning?

METHODS

The quasi-experimental design with pretest-posttest control groups was adopted to determine the effectiveness of the educational game-integrated group research method and of the existing teaching implementation in the teaching process of "regulatory system" issue in 7th grade science course (McMillan & Schumacher, 2006; Christensen, 2004; Büyüköztürk et al., 2012). Prior Knowledge Test (PKT) and Attitudes towards School Scale (ATSS) were administered as a pretest before the implementation. While one of the research groups was assigned as the educational game-integrated group research method, the other group was assigned as the current curriculum proposed by the Ministry of Education method. The Academic Achievement Test (AAT) and ATSS were administered to both groups as a posttest after the implementation. AAT was re-administered as a delayed-posttest 8 weeks later following the end of the implementation. The implementation schedule is given below in Table 1.

Table 1. *Pretest-posttest control group quasi-experimental design schedule*

Groups	Pretest	Experiment	Posttest
Experimental	PKT, ATSS	Educational Game-Integrated Cooperative Learning Model	AAT, ATSS, AAT - retention
Control	PKT, ATSS	Existing teaching implementation	AAT, ATSS, AAT - retention

a) The Study Group

The study group of this research consists of 54 students attending in two different groups of 7th grade in a middle school in rural area of Erzurum Providence in Turkey during the 2015-2016 academic years. The half of the students were assigned as the experimental group (n=27) who had educational game-integrated research method while the others were assigned as the control group (n=27) who had traditional method. Gender, economic income level of the family, and game playing time per day for students participating in research are given below.

The distributions of the students in experimental and control groups according to gender variables are given in Figure 1.

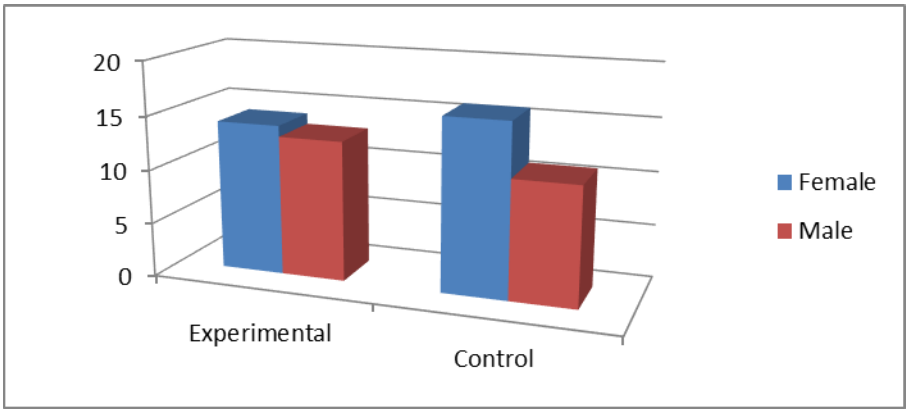


Figure 1. *Gender distributions*

According to Figure 1, the experimental group consisted of 14 female and 13 male students while control group consisted of 16 female and 11 male students. Income levels of students' parents are given in Figure 2.

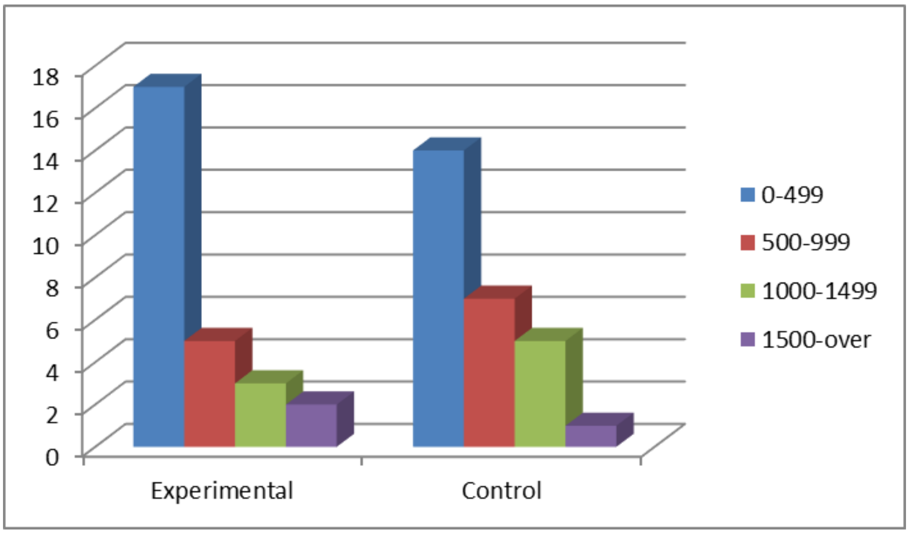


Figure 1. Income levels of parents

According to Figure 2, many of the students come from low-income families. In addition, most of the families have a monthly income of less than ₺500. Since it is important to select individuals for the groups to have different characteristics from each other while

forming the cooperative learning groups, it will be beneficial to consider the variables such as gender and socioeconomic structure in addition to the academic achievement variable during formation of the groups. Intra-group diversity will be increased in this way.
Game play times of students per day are given Figure 3.

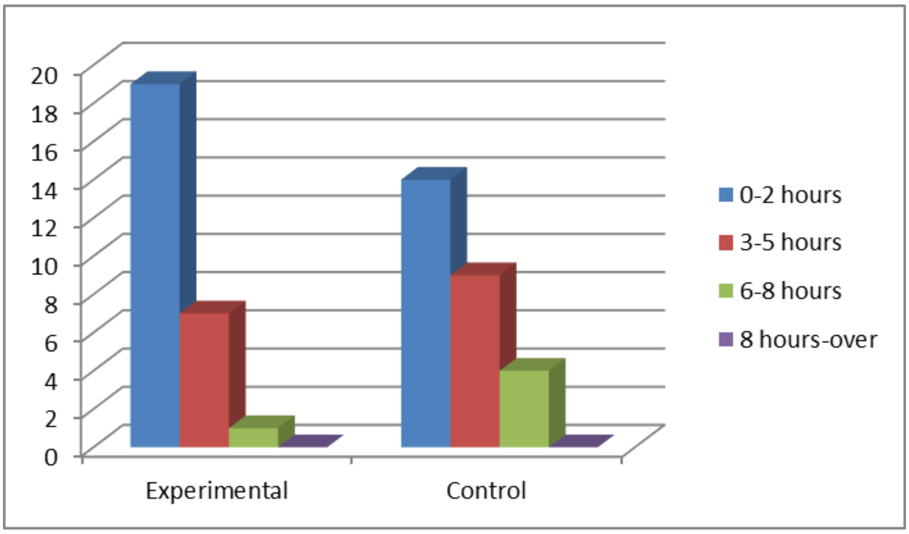


Figure 2. Game play times of students per day

According to Figure 3, students spend very little time for playing digital games in both groups. Since the game is a basic development for children, the short playing times are not sufficient to meet these needs. In addition, digital games are more inadequate than other games in terms of sharing, cooperating, respecting to different thoughts, freely defending their own ideas, and being active. Considering the play times, less playing students were taken in experimental group to play more. There are also special education students with learning disability and adaptation problems in both groups. Students in both groups have a similar problem of learning difficulty. The students feel that they don't have proficiency as much as other students because of this problem. Because of their isolation by their teachers and friends, they have a problem of adaptation to their classes and lessons.

b) Data Collection Tools

PKT was employed to determine the prior knowledge levels of students. ATSS was used to observe any possible change in attitudes towards school. Finally, AAT was implemented to identify academic achievement.

Prior Knowledge Test (PKT)

The Prior Knowledge Test was prepared by the researcher which was created through the questions asked in the Ministry of National Education 6th grade open middle school exams in order to measure the prior knowledge levels students. The test items were presented to 3 experts in science education to ensure content validity. The experts stated that there was no problem with the content of the test but suggested some arrangements only for the font punctuation and the page layout. After the completion the necessary adjustments, a pilot experiment was carried out with 98 seventh grade students. The test was finalized after the pilot experiment with the 25 items. While 4 points were given to correct answers, 0 point was given to incorrect answers and the questions left unanswered. KR-20 reliability coefficient was calculated to be 0.88.

Academic Achievement Test (AAT)

The Academic Achievement Test (AAT) used in the present study was prepared based on the acquisitions of the “regulatory system” issues which is covered in the 7th grade, in order to determine the effectiveness of the methods implemented in the groups. A table of specifications was prepared to ensure the content validity of the test. Expert opinions were taken to ensure its construct validity. After completing the necessary adjustments, a pilot experiment was carried out with 100 students at eight grades. At the end of the analyses, the Cronbach’s alpha reliability coefficient was calculated to be 0.81 for the test. The final version of the test consisted of 25 items. While 4 points were given to correct answers, 0 point was given to incorrect answers and the questions left unanswered.

The Attitudes towards School Scale (ATSS)

The Attitudes towards School Scale was developed by Coşkun (2004) to identify the attitudes towards school for the students aged from 11 to 15 years old. ATSS is a 3-point Likert-type scale and made up of 5 positive and 5 negative items (i.e. 10 items in total). Cronbach’s alpha reliability coefficient was calculated to be 0.74 for the ATSS. Cronbach’s alpha reliability coefficient was calculated to be 0.72 for this research.

c) Data Analysis

The obtained data were analyzed via SPSS in order to find answers to the research questions. Parametric analyzes have been preferred since the data are normally distributed. Descriptive statistics and independent group t-test were used to determine whether the differences were significant between the students in experimental group and the control group in terms of prior knowledge, academic achievement, attitude towards school, and retention of knowledge.

d) Experiment

The implementation was performed by researchers in both groups and lasted in 4 weeks (16 lesson hours) including the implementation of pretest and posttest. In this study, it was targeted that students explain names and tasks of endocrine glands, show their place in body on model, explain names and functions of hormones, indicate diseases and treatments in case of hormonal disorder.

Implementation of the Program-Based Learning

In the group set as the control group, lessons were conducted in accordance with the curriculum specified by the Ministry of National Education of the Republic of Turkey (MEB). Existing teaching implementation pursues the national education program with constructivist approach. The lessons were conducted as recommended for 16 course hours set by MEB. All the recommended activities were performed. Initially, the researcher did research on the subject and prepared a work plan. The textbook, the workbook, the teacher’s guidebook, and some other resources were used in that preparation stage. The researcher just carried out the activities included in the textbook as specified in the curriculum.

Implementation of the Educational Game-Integrated Group Research Method

In the group set as the experimental group, lessons were conducted through the educational game-integrated group research method during 16 course hours. Initially, the students were informed how the implementation would be performed. They were informed by their teacher that after completing the 4-hours group work, they would play a game during the 2-hours course period, and their achievement in that game would be directly associated with the performance displayed by them in the previous 4-hours course period. These explanations were made in order to set the internal motivation of students in motion and make them effectively participate in the learning process. By this means, the pre-game preparations of students were made more meaningful for them and they were motivated to study. As a result, 4-hours educational processes conducted in the classroom were made more efficient. First, the students were divided into heterogeneous groups based on their prior knowledge and gender. The groups were asked to elect a president and find a name for their group. After that, during 4 course hours, the students in the classroom environment did research and collected information on the relevant subject in cooperative groups and then worked on the information that they had collected and run a report based on such information in group. The same procedure was implemented in all the groups. The teacher observed and monitored the groups and intervened in when necessary. Normally, the last stage of the group research method includes group presentations. However, the presentation stage was replaced by an educational game in the present study. This educational game was developed by the researchers under the name of "Know-Win". This game played with a total of 28 game cards. One face of a game card includes the introduction and functions of an organ, the characteristics of an endocrine gland, the functions of a hormone, or the explanation of a disease. The back face of the card includes the name of another organ, endocrine gland, hormone, or disease. Only one of the game cards has a 1 (in figure) on the face including explanations. Sample game cards are shown in Figure 4 and photos of the implementation are presented in the appendices.

Figure 2. *Examples of game cards*

Each student in both groups is provided a game card, and the other cards are kept by the teacher. In this way, the teacher also participated in the process. The student having the card with "1" on it starts the game by reading the explanation written on it. In response to the explanation read by this student, another student having this explanation in another group tells the name of the organ, endocrine gland, hormone, or disease mentioned in the explanation and reads the explanation written on his/her card. The student holding the card that includes what the explanation refers to tells the structure to which such explanation belongs and reads the explanation on his/her card. The cycle is completed in this way. After the first cycle completed, games are played one after another. To determine the winning group in the game, a plus (+) is given for each correct answer from the groups, and a minus (-) is given for each incorrect answer from the groups. Last, the number of minuses is subtracted from the number of pluses, and the obtained result is divided by the number of the members in the group. Thus, the group having the highest score wins the game.

FINDINGS

The findings obtained through the analysis of the data are presented below.

PKT

Table 2 shows independent group t-test results for the data obtained from PKT that was administered to determine the prior knowledge levels of students before the experiment.

Table 1. *Independent group t-test results for the data obtained from PKT*

Group	N	X	ss	df	t	p*
Experimental	27	66.04	23.25	52	1.112	.271
Control	27	60.00	15.96			

$p>0.05$

According to the Table 2, there was no statistically significant difference ($t_{(52)}=1.112$; $p>0.05$) between the prior knowledge levels of the experimental group implemented the educational game-integrated group research method ($X_{experimental}=66.04$) and the control group implemented the program-based learning ($X_{control}=60,00$).

AAT

Table 3 shows independent group t-test results for the data obtained from AAT that was administered to determine the academic achievement levels of students after the implementation.

Table 2. *Independent group t-test results for the data obtained from AAT*

Group	N	X	sd	df	t	p*
Experimental	27	72.59	22.67	52	3.122	.003
Control	27	51.85	26.03			

$p<0.05$

According to the Table 3, the experimental group students implemented the educational game-integrated group research method ($X_{experimental}=72.59$) had statistically significant higher ($t_{(52)}=3.122$; $p<0,05$; $\eta^2=0.16$) AAT scores compared to the control group students implemented program-based learning ($X_{control}=51.85$). 16% of the variance observed in the student academic achievement derived from the implemented method. According to Cohen (1988), this value represents a big effect size.

ATSS

Table 4 shows independent group t-test results for the data obtained from ATSS that was administered to determine the student attitudes towards school before the experiment.

Table 3. *Independent group t-test results for the data obtained from ATSS as a pretest*

Group	N	X	ss	df	t	p*
Experimental	27	24.81	3.57	52	1.746	.087
Control	27	23.11	3.60			

$p>0.05$

According to Table 4, there was no statistically significant difference ($t_{(52)}$=1.746; p>0.05) between the attitudes towards school scores of the experimental group students implemented the educational game-integrated group research method (X=24.81) and the control group students implemented the program-based learning (X=23.11) before the experiment.

ATSS was also administered as a posttest in order to determine the effects of the educational game-integrated group research method and the program-based learning on the student attitudes towards school. Table 5 below presents the analysis results for the data obtained from the scale.

Table 4. Independent group t-test results for the data obtained from ATSS as a posttest

Group	N	X	sd	df	t	p*
Experimental	27	25.41	2.79	52	2.054	.045
Control	27	23.48	3.99			

p<0.05

According to the Table 5, the experimental group students implemented the educational game-integrated group research method ($X_{experimental}$=25.41) had statistically significant higher ($t_{(52)}$=2.054; p<0.05; η^2 =0.07) ATSS scores after the experiment compared to the control group students implemented the program-based learning ($X_{control}$=23.48). 7% of the variance observed in the student attitudes towards school derived from the employed method. According to Cohen (1988), this value represents a medium effect size.

AAT-retention

To see the student levels of permanent learning, AAT was re-administered 8 weeks later following the end of the implementation. Table 6 shows the independent group t-test results for the data obtained.

Table 6. *Independent group t-test results for the data obtained from AAT-retention*

Group	N	X	ss	df	t	p*
Experimental	27	71.48	21.47	52	4.781	.000
Control	27	46.74	16.18			

p<0.05

According to the Table 6, there was a statistically significant difference between the groups in favor of the experimental group students implemented to the educational game-integrated group research method ($X_{experimental}$=71.48; $X_{control}$=46.74 $t_{(52)}$=4.781; p<0.05; η^2 =0.31) in terms of the retention of what was learned. Cohen's effect size (1988) that was calculated to see the source of the rise in the experimental group students' levels of retention was found to be r^2=0.31. In this regard, it was seen that the implemented method had an enormous effect of 31% on retention.

DISCUSSION and CONCLUSION

This study was performed to explore the effect of teaching the "regulatory system" issue, which is covered in the science course, through the educational game-integrated group research method on students' academic achievement levels and attitudes towards school. First, the analysis of the data obtained from PKT, which was administered in the beginning, indicated that there was no statistically significant difference between the readiness levels of the students participating in the study (Table 2). In this sense, it can be said that the academic levels of the participating students were close to each other in the beginning.

According to the analysis results of the data obtained from AAT, which was administered to determine the effects of the educational game-integrated group research method and the program-based learning on the academic achievement of students, the students implemented the educational game-integrated group research method had statistically significant higher mean scores on academic achievement compared to the students implemented the program-based learning (Table 3). Based on these results, it can be said that the educational game-integrated group research method is more effective in improving academic achievement of students. The results obtained in the present study were consistent with the results of other studies focusing on the cooperative learning model and educational game method (Hsiung, 2010; Carpenter, 2003; Johnson & Johnson, 1999; Önder & Sılay, 2015; Doymuş, 2007; Evcim & İpek, 2013; Genç & Şahin, 2015; Bayat, Kılıçaslan & Şentürk, 2014; Saracaloğlu & Aldan Karademir, 2009; Uzun, 2012; Kaya & Elgün, 2015). The reasons for this kind of effect may be as follows: students have increased their levels of motivations in classes where the cooperative learning model and educational game method are implemented; they are allowed to defend their ideas freely; exploration is encouraged; and they are provided with an active learning environment where they can achieve effective learning (Şimşek, 2007; Önder & Sılay, 2015; Leikin & Zaslavsky 1997; Cooper et al., 1984; Nelson Legall, 1992; Karamustafaoğlu & Kaya, 2013; Bayırtepe & Tüzün, 2007; Coşkun, Akarsu & Karaiper, 2012).

The analysis results of the data obtained from the administered ATSS to determine the effects of the methods employed in the present study on attitudes towards school indicate that while there was no statistically significant differences between the two groups in terms of attitude towards school before the experiment, there was a statistically significant difference between the groups in favor of the students mplemented the educational game-integrated group research method after the experiment (Table 4-5). The reasons for this finding may be as follows: students having education in the classes where the cooperative learning model and educational games are implemented have higher critical thinking, problem-solving, and motivation levels and more positive attitudes towards science lessons, school, themselves, and their friends (Koç, 2014; Genç & Şahin, 2015 Coşkun, Akarsu & Karaiper, 2012; Savaş & Gülüm, 2014; Karamustafaoğlu & Kaya, 2013; Önen, Demir & Şahin, 2012; Bayırtepe & Tüzün, 2007).

To identify the retention of learning among the students, AAT was re-administered as a retention test 8 weeks later following the end of the implementation. The analysis results of the obtained data showed that the students in the group implemented the educational game-integrated group research method had higher learning levels (Table 6). The reason for this finding may be through the educational game-integrated group research method; the students participated in the learning process in an active way rather than passive way; understood the subject better without just memorizing the information; transferred the knowledge more easily, and achieved a higher level learning through the improvement in their cognitive structures. This result of the present study is consistent with the results of the studies in the literature that suggest the cooperative learning model and educational games lead to permanent learning (Çalıklar, 2015; Evcim & İpek, 2013; Savaş & Gülüm, 2014; Yıldırım & Girgin, 2012).

During the informal observations conducted throughout the research, it was seen that the students in the experimental group showed more interest in lessons, more willing to participate in activities, and enjoyed a lot during the lessons. It was observed that the students did not even want to take a break, preferred the game to the break, and tirelessly wanted to play again and again. Similar results were reported in other studies conducted on educational games (Bayat, Kılıçaslan & Şentürk, 2014; Saracaloğlu & Aldan Karademir, 2009). There were two students having learning disability and adaptation problems in the classes. One of them was included in the control group, and the other one was included in the experimental group. During the informal observations, no positive improvement was seen for the student having learning disability in the control group whereas the student having learning disability in the experimental group learned majority of the concepts intended in the covered subject, wished to participate in the course activities during the game, and tried to express his opinions by asking permission to talk. The reason underlying this result may be the psychological effect of the games on children.

Based on the results obtained in this study, it is considered that implementing the educational game method through integration with active learning models and methods will improve internal motivation of students, make the employed method more effective, and bring a lot of educational contributions. Hence, it is thought that games can be implemented with different learning models and methods on different subjects. The related literature pointed out that educational games are mostly used after a subject is covered through the program-based learning or to support another teaching method that is taken as basis in the teaching process (Gençer & Karamustafaoğlu, 2014; Bayat, Kılıçaslan & Şentürk, 2014; Kaya & Elgün, 2015). Based on the measurements and observations carried out during the research, it can be stated that games eliminated a lot of concerns of students about the subject and enabled them actively participate in the learning process. It was seen that highly efficient educational outcomes were obtained through the integration of educational games into other methods and techniques. Due the fact that integrating educational games into active learning methods lead to such positive outcomes, it can be considered that using educational games as an active teaching method on its own will provide greater benefits as much as learning through games be effective. The literature indicates that mostly digital games that are played in the virtual environment are used in the educational field. However, it was thought that games which students can actively play in the classroom environment and whereby they can improve their communication with their friends, express themselves comfortably, and engage in activities related to their affective and psychomotor development may be more effective in providing students with the intended basic behaviors.

REFERENCES

Açıkgöz, K. Ü. (1992). *İşbirlikli öğrenme: Kuram, araştırma ve uygulama*. Malatya: Uğurel Matbaası.

Adıgüzel, Ö. (2010). *Eğitimde Yaratıcı Drama.* Ankara: Naturel Yayınevi.

Akar, S. (2012). *Fen ve teknoloji öğretmenlerinin işbirlikli öğrenme modeli hakkında bilgilendirilmesi, bu modeli sınıfta uygulamaları ve elde edilen sonuçların değerlendirilmesi: kars il örneği*. Unpublished doctoral dissertation, Atatürk University Institute of Educational Sciences, Erzurum.

Bayat, S., Kılıçaslan, H., & Şentürk, Ş. (2014). Fen ve teknoloji dersinde eğitsel oyunların yedinci sınıf öğrencilerinin akademik başarısına etkisinin incelenmesi. *Abant İzzet Baysal Üniversitesi Eğitim Fakültesi Dergisi*, 14 (2), 204-216.

Bayırtepe, E. & Tüzün, H. (2007). Oyun-Tabanlı öğrenme ortamlarının öğrencilerin bilgisayar dersindeki başarıları ve öz-yeterlik algıları üzerine etkileri. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi,* 33, 41-54.

Bozkurt, O. & Olgun, Ö. S. (2005). Fen ve teknoloji eğitiminde bilimsel süreç becerileri. M. Aydoğdu and T. Kesercioğlu (Ed.). *İlköğretimde Fen ve Teknoloji Öğretimi [Science & Technology Education in Primary Education]*. Ankara: Anı.

Büyüköztürk, Ş., Kılıç-Çakmak, E., Akgün, Ö. E., Karadeniz, Ş. & Demirel, F. (2012). *Bilimsel araştırma yöntemleri*. Ankara: Pegem.

Carpenter, S. R. (2003). Incorporation of a cooperative learning technique in organic chemistry. *Journal of Chemical Education*, 80, 330-332.

Christensen, L. B. (2004). *Experimental Methodology.* United States of America: Pearson Education

Christison, M.A. (1990). Cooperative learning in the EFL classroom. *English Teaching Forum*, 28, 6-9.

Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd ed.). Hillsdale, NJ: Lawrence Earlbaum Associates.

Cooper, J., Prescott, S., Cook, L., Smith, L., Mueck, R., & Cuseo, J. (1984). *Cooperative Learning and College Instruction- Effective Use of Student Learning Teams*. California State University Foundation Publication, 41-65.

Coşkun, H., Akarsu, B. & Karaiper, A. İ. (2012). Bilim öyküleri içeren eğitsel oyunların fen ve teknoloji dersindeki öğrencilerin akademik başarılarına etkisi. *Ahi Evran Üniversitesi Kırşehir Eğitim Fakültesi Dergisi (KEFAD),* 13(1), 93- 109.

Coşkun, L. (2004). *Yatılı, taşımalı ve "normal" eğitim yapılan ilköğretim okulu öğrencilerinde akademik başarı, okula ilişkin tutum, algılanan sosyal destek ve davranış-uyum sorunları arasındaki ilişkiler*. Unpublished Master's Thesis. Hacettepe University, Ankara.

Çalıklar, Ş. (2015). Atom kuramlarının öğretiminde öğrencilerin akademik başarıları, epistemolojik inançları ve öğrenmelerinin kalıcılığı üzerine öğrenci takımları başarı bölümleri ve takım oyun turnuva yönteminin etkisi. Unpublished master's thesis, Atatürk University Institute of Educational Sciences, Erzurum.

Çalışkan, F. (2005). *İlköğretim 4. sınıf Sosyal Bilgiler dersinde aktif öğrenme yöntemlerinden çözümlemeli öykü yönteminin öğrencilerin akademik başarılarına, tutumlarına ve aktif öğrenme düzeylerine*. Unpublished Master's Thesis, Mustafa Kemal University, Institute of Social Sciences.

Çavuş, R., Kulak, B., Berk, H. & Öztuna Kaplan, A. (2011). *Fen ve teknoloji öğretiminde oyun etkinlikleri ve günlük hayattaki oyunların derse uyarlanması.* Paper presented at IGEDER Science & Technology Teachers' Summit, Istanbul, Turkey.

Çepni S. (Ed.). (2011). *Fen ve teknoloji öğretimi. (9th Edition).* Ankara: Pegem.

Doymuş, K. (2007). Effects of a cooperative learning strategy on teaching and learning phases of matter and one-component phase diagrams. *Journal of Chemical Education, 84* (11), 1857-1860.

Doymuş, K., Karaçöp, A. & Şimşek, U. (2010). Effects of Jigsaw and Animation Techniques on Students' Understanding of Concepts and Subjects in Electrochemistry. Educational Technology Research and Development, 58 (6), 671-691.

Dönmez, N. B. (1999). *Oyun kitabı.* Istanbul: Esin.

Evcim, H. & İpek, Ö. F. (2013). Effects of Jigsaw II on academic achievement in English prep classes. *Procedia – Social and Behavioral Sciences,* 70, 1651-1659.

Genç, M., & Şahin, F. (2015). İşbirlikli Öğrenmenin Başarıya ve Tutuma Etkisi. *Necatibey Eğitim Fakültesi Elektronik Fen ve Matematik Eğitimi Dergisi*, 9 (1), 375-396.

Gök, Ö., Doğan, A., Doymuş, K. & Karaçöp, A. (2009). İşbirlikçi öğrenme yönteminin ilköğretim öğrencilerinin akademik başarılarına ve fene olan tutumlarına etkileri. *Gazi Eğitim Fakültesi Dergisi,* 29 (1), 193-209.

Hennessy, D. & Evans, R. (2006). Small-group learning in the community college classroom. *The Community College Enterprise,* 12 (1), 93-110.

Hsiung, C. M (2010). An experimental investigation into the efficiency of cooperative learning with consideration of multiple grouping criteria. *European Journal of Engineering Education*, 35 (6), 679-692.

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

Karamustafaoğlu, O. & Kaya, M:. (2013). Eğitsel oyunlarla "yansıma ve aynalar" konusunun öğretimi: yansımalı koşu örneği. *Araştırma Temelli Etkinlik Dergisi*, 3(2), 41-49.

Kaya, S., & Elgün, A. (2015). Eğitsel oyunlar ile desteklenmiş fen öğretiminin ilkokul öğrencilerinin akademik başarısına etkisi. *Kastamonu Eğitim Dergisi*, 23 (1), 329-342.

Koç, Y. (2014). *Fen ve teknoloji öğretmenlerinin işbirlikli öğrenme modeli hakkında bilgilendirilmesi, bu modeli sınıfta uygulamaları ve elde edilen sonuçların değerlendirilmesi.* Unpublished master's thesis, Atatürk University, Institute of Educational Sciences, Erzurum.

Koç, Y., Şimşek, Ü. & Fırat, M. (2013). Işık ünitesinin öğretiminde okuma-yazma-uygulama yönteminin etkisi. *Erzican Eğitim Fakültesi Dergisi*, 15 (2), 204-225.

Leikin, R., & Zaslavsky, O. (1997). Facilitating student interactions in mathematics in a cooperative learning setting, 350. Journal of Research in Mathematics Education, 28 (3), 331-359.

McMillan, J. H. & Schumacher, S., 2006. Research in Education: Evidence-Based Inquiry. Sixth Edition. Boston, MA: Allyn and Bacon.

MEB. (2006). İlköğretim Fen ve Teknoloji Dersi (6, 7 ve 8. Sınıflar) Öğretim Programı. Talim ve Terbiye Kurulu *Başkanlığı:* Ankara.

Nelson-Legall, S. (1992). Children's Instrumental Help-Seeking. It's Role in the Social Acquisition and Construction of Knowledge. In Lazarowitz Ed. Interaction In Cooperative Groups: Theoretical Anatomy of Group Learning, 120-141, NY,NY: Cambridge University Press.

Okur Akçay, N., Doymuş, K. (2014). The Effect of Different Methods of Cooperative Learning Model on Academic Achievement in Physics. Journal of Science Education, 11 (4).

Önder, F. & Sılay, İ. (2015). İşbirlikli Öğrenme Yönteminin Farklı Öğrenme Stillerine Sahip Öğrencilerin Fizik Dersi Başarısına Etkisi. *Kastamonu Eğitim Dergisi*, 23 (2), 843-860.

Önen, F., Demir, S. & Şahin, F. (2012). Fen öğretmen adaylarının oyunlara ilişkin görüşleri ve hazırladıkları oyunların değerlendirilmesi. *Ahi Evran Üniversitesi Kırşehir Eğitim Fakültesi Dergisi (KEFAD),* 13 (3), 299-318.

Rollnick, M., Lubben, F., Lotz, S. & Dlamini, B. (2002). What Do under Prepared Students Learn about Measurement from Introductory Laboratory Work. *Research in Science Education,* 32, 1-18.

Saracaloğlu, A. S. & Aldan Karademir, Ç. (2009). Eğitsel oyun temelli fen ve teknoloji öğretiminin öğrenci başarısına etkisi. *VIII. Ulusal Sınıf Öğretmenliği Eğitimi S*empozyumu*, Bildiri Kitabı*. 21-23 May 2009. Osmangazi University: Eskişehir. 1098-1107.

Şaşmaz Ören F. & Erduran Avcı D. (2004). Eğitimsel oyunla öğretimin fen bilgisi dersi "güneş sistemi ve gezegenler" konusunda akademik başarı üzerine etkisi *Ondokuz Mayıs Üniversitesi Eğitim Fakültesi Dergisi*,18, 67-76.

Savaş, E., & Gülüm, K. (2014). Geleneksel oyunlarla öğretim yöntemi uygulamasının başarı ve kalıcılık üzerine etkisi. *Trakya Üniversitesi Sosyal Bilimler Dergisi,* 16 (1), 175-194.

Siegel, C. (2005). An ethnographic inquiry of cooperative learning implementation. *Journal of School Psychology*, 43 (3), 219–239.

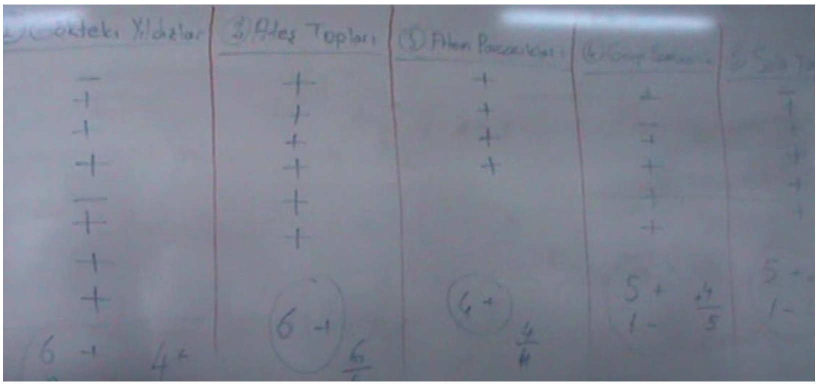
Şimşek, Ü. (2007). Çözeltiler ve kimyasal denge konularında uygulanan jigsaw ve birlikte öğrenme tekniklerinin öğrencilerin maddenin tanecikli yapıda öğrenmeleri ve akademik başarıları üzerine etkisi. *Unpublished Doctoral Dissertation, Atatürk University Institute of Science, Erzurum.*

Sökmen N., Bayram, H., Solan, Ü., Savcı, H. & Gürdal, A. (1997). Kavram haritasının fen bilgisi başarısına etkisi. *Marmara Üniversitesi Eğitim Fakültesi Dergisi,* 142–149.

Uzuntiryaki, E., Çakır, H. & Geban, Ö. (2001). Kavram haritaları ve kavramsal değişim metinlerinin öğrencilerin "asit-bazlar" konusundaki kavram yanılgılarının giderilmesine etkisi. *Yeni Bin Yılın Basında Fen Bilimleri Eğitimi Sempozyumu* (7–8 Eylül 2001), Istanbul. Bildiriler Kitabı, 281–284, 2001 Maltepe University Faculty of Education.

Yıldırım, B.& Girgin, S. (2012). The Effects of Cooperative Learning Method on the Achievements and Retention of Knowledge on Genetics Unit Learned by the 8th Grade Students. Elementary Education Online, 11(4), 958-965.

Appendices (photos from the application process)



TÜRK FEN EĞİTİMİ DERGİSİ
Yıl 15, Sayı 3, Eylül 2018

Journal of
TURKISH SCIENCE EDUCATION
Volume 15, Issue 3, September 2018

http://www.tused.org

Teaching about Gauss's Law by Combining Analogical and Extreme Case Reasoning

Andrej Vidak[1], Senad Odžak[2], Vaneš Mešić[3]

[1] Teaching Assistant, Faculty of Chemical Engineering and Technology, University of Zagreb, Croatia, ORCID ID: 0000-0002-3669-6762
[2] Associate Professor, Faculty of Science, University of Sarajevo, Bosnia and Herzegovina.
[3] Associate Professor, Faculty of Science, University of Sarajevo, Bosnia and Herzegovina.

Received: 17.10.2017 **Revised:** 23.5.2018 **Accepted:** 19.06.2018

The original language of article is English (v.15, n.3, September 2018, pp.106-127, doi: 10.12973/tused.10240a)

ABSTRACT

It is well known that many students have tremendous difficulties with applying Gauss's law for purposes of solving quantitative as well as qualitative problems. In this study, it was investigated how understanding of Gauss's law can be facilitated by analyzing the superposition of electric field vectors for increasingly complex geometric configurations of charges. Actually, in the spring semester of academic year 2016/2017, a pretest-posttest quasi-experiment was performed with 180 students from the Faculty of Chemical Engineering and Technology in Zagreb, Croatia. The student sample has been divided into three control subgroups and three experimental subgroups. Control subgroups (Nc=93) received a traditional teaching treatment while in the experimental subgroups (Ne=87) students showed how reasoning about superposition of electric field vectors can be transferred from relatively simple configurations of charges to more complex ones. At the posttest, students from the experimental group proved to be significantly more effective in solving qualitative problems on Gauss's law. The results from our study support the idea that development of analogical, visually rich models facilitates the meaningful learning.

Keywords: Gauss's law, superposition of electric field, analogies, extreme case reasoning.

INTRODUCTION

Electricity has intrigued people since ancient times. As a matter of fact, people reasoned about the nature of lightning (Viegas, 2007), conducted experiments with static electricity (Stewart, 2001) and reported about some interesting electrical phenomena in the animal world (Moller, 1991) even long before adopting the modern understanding of electricity. However, it took many centuries until the development of a more coherent view about electricity. Significant contributions to a better understanding of electrical phenomena have been made by Carl Friedrich Gauss. Specifically, Gauss came to the conclusion that the net electric flux through an arbitrary closed surface is proportional to the net electric charge within that closed surface regardless of electric charge distribution and shape of the surface. This conclusion has been known as Gauss's law and is one of the four Maxwell equations that form the basis of classical electrodynamics theory (Jackson, 1999). The importance of Gauss's law particularly

Corresponding author e-mail: avidak@fkit.hr © ISSN:1304-6020

stems from the fact that it can be used to calculate the electric field at arbitrary points. Thus, it can be concluded that students' ability to apply Gauss's law in qualitative and quantitative contexts represents an important requirement in typical electromagnetism curricula at the university level. However, past researches have shown that Gauss's law is a very challenging topic for most students (Aubrecht & Raduta, 2005; Guisasola, lmudi, Salinas, Zuza, & Ceberio, 2008; Maries, Lin, & Singh, 2017; Lin, Maries, & Singh, 2012; Pepper, Chasteen, Pollock, & Perkins, 2010; Singh, 2006). Concretely, it has been found that students in introductory physics courses often use already derived formulae to calculate the electric field without considering the assumptions about symmetry conditions (Traxler, Black, & Thompson, 2007). As a matter of fact, students often memorize formulae of the magnitude of electric field without paying attention to symmetry considerations and they have difficulties with identifying situations where Gauss's law is applicable (Singh, 2006).

Many of the identified difficulties are probably related to an abstract nature of electrostatic examples which are typically considered in lectures about Gauss's law (Demirci & Çirkinoglu, 2004; Isvan & Singh, 2006). Another possible source of students' difficulties with Gauss's law is related to the fact that many students have a relatively weak mathematical (integral calculus) background when they first introduced about Gauss's law (Grundmeier, Hansen, & Sousa, 2006). Concretely, Bollen, van Kampen and De Cock (2015) found that students often have poor understanding of operators, graphical representation of vector fields and have problems with conceptual interpretation of calculus even they know how to use. So, the requirement often results in cognitive overload in order to combine abstract physics concepts with relatively sophisticated mathematical tools. As a matter of fact, past studies showed that students have difficulties with understanding the concept of electric field as well as with applying integral calculus and it is no surprise that they are struggling with applying integral calculus for purposes of reasoning about an electric field (Bollen et al. 2015; Pepper, Chasteen, Pollock, & Perkins, 2012).

The reasoning is highly demanding and may result in cognitive overload since require combining multiple knowledge elements (Adams, 2015; Bloom, & Krathwohl, 1956; Sorden, 2005; Sweller, Van Merrienboer, & Pass, 1998). The probability of cognitive overload can be reduced by breaking down the lecture into smaller sections using effective external visualizations, providing explicit cues and making sure that students have a solid understanding of basic concepts/examples before considering more complex ones. Within the context of learning and teaching about Gauss's law, cognitive overload may be prevented by relating it to the principle of superposition of electric field for relatively simple geometrical configurations of point charges before going on with more complex configurations and continuous charge distributions. So, it is necessary that students have expertise in superposition of vectors which is a prerequisite for finding the net electric force/field at an arbitrary point in order to develop higher expertise in Gauss's law (Sing, 2006). However, earlier researches showed that students have substantial difficulties in understanding the principles of superposition and its application in tasks that involve the electric field concept (Bagno & Elyon, 1997; Bagno, Eylon, & Ganiel, 2000; Li & Singh, 2017; Viennot & Rainson, 1992). Indeed, Aubrecht (2005) found that for many students it is difficult to transfer their knowledge of the superposition principle from the context of mechanics (where it first introduced) to electromagnetism. At the same time, Singh (2006) pointed out that understanding of the principle of superposition of electric field is a prerequisite for effective usage of Gauss's law and instructional strategies should take into account in students' difficulties with the principle of superposition that are focused on improving student understanding of Gauss's law. In last, Bollen et al. (2015) suggested that teachers should put an additional effort to present more graphical and conceptual examples in order to explicitly relate the abstract equations to vivid electrical phenomena.

It has been generally recognized that there is a need for a teaching method which will foster students' ability to effectively apply the Gauss's law in qualitative and quantitative contexts (Bollen et al., 2015; Pepper et al., 2010). The ability to solve qualitative problems requires not only developing expertise in mathematics but also development of visually rich mental models (Greca & Moreira, 1997). On the other hand, development of visually rich mental models of physics phenomena is often associated with analogical and extreme case reasoning. So, analogical reasoning is characterized as transferring information or meaning from a particular source domain to a target domain (Maymoona & Sulaiman, 2015; Podolefsky & Finkelstein, 2006; Sevim, 2013). In addition, extreme case reasoning happens when a situation E (extreme case) is suggested in order to facilitate reasoning about a situation A (the target) in which some aspect of situation A has been maximized or minimized (Stephens & Clement, 2009). Using analogies and extreme cases was at the heart of some of the greatest discoveries in history of physics such as the inertia concept discovered by Galilei (Einstein & Infeld, 1938; Nersessian, 1999). When it comes to electromagnetism, it should be noted that Thompson developed formal analogies between electrostatics and heat flow while Maxwell drew analogies between movement of incompressible fluid and electrostatics (Silva, 2007). Past researches showed that using analogies and extreme cases may facilitate learning of abstract and counterintuitive concepts (Clement, 1991, 1993; Stephens & Clement, 2009, 2010; Zietsmann & Clement, 1997). This can be related to the fact that analogical and extreme case reasoning fosters the development of imaginable, intuitive, and grounded explanatory models (Clement, 1993). On the other hand, simultaneous reasoning about the source and target domain can result in cognitive overload in ill-designed analogy-based instruction (Johnstone & Al-Naeme, 1991; Lin & Chiu, 2017). In order to optimize the cognitive load, researchers have suggested strategies such as breaking down the lecture into smaller "chunks" and providing explicit clues as well as using external visualizations and personally familiar analogical anchors (Van Merrienboer & Sweller, 2005).

In this study, it is purposed to present how reasoning about net electric field (at an arbitrary point) for an one-dimensional configuration of point charges (source domain) can be gradually transferred to more complex contexts that require reasoning about net electric field (at an arbitrary point) that results from a three-dimensional, continuous distribution of charges (target domain). Concretely, in our experimental teaching intervention, equidistant charges were used on a straight line as an anchoring example and showed how to apply the superposition principle in that context. Thereafter, the superposition principle has been applied for charges fixed in vertices of a square and octagon as well as to a circle as an extreme case of a polygon when the number of edges tends to infinity. Finally, it was showed that how reasoning about superposition from the context of uniformly charged circles can be transferred to the context of charged spheres. Thereby, the volume of a charged sphere has been conceptualized as an extreme case of a surface charged spherical shell – it can be thought as consisting of a large number of concentric, surface charged shells of varying radii.

Purpose

In this study, it was aimed to investigate whether analogies and extreme cases used teaching intervention can foster students' ability to apply Gauss's law in qualitative and quantitative contexts. Indeed, analogies were drawn between applying the principle of superposition for 1D/2D configurations of charges (source domain) and 3D configurations of charges (target domain), and a volume charged sphere has been conceptualized as an extreme case of a surface charged sphere.

The significance of this study is related to the fact that it provides an example of how developing visually rich, analogical models can foster the students' ability to transfer their knowledge to new contexts.

DESIGN AND METHODS

a) Research design

In this study, a pretest-posttest quasi-experiment was implemented with the aim to investigate whether enriching traditional teaching with analogical and extreme case reasoning can help the students to develop a higher ability for solving qualitative and quantitative problems within the context of Gauss's law. The student sample has been divided into three control and three experimental subgroups. The experimental subgroups received a teaching treatment enriched by analogies and extreme cases, while the three control subgroups received traditional practice sessions in which most of the time the teaching assistant modeled solving of quantitative problems. Both treatments lasted for 2 teaching hours (90 minutes). All subgroups took the pretest one week before the teaching treatment and posttest right after the treatment. The time for finishing the pretest and posttest was set to 15 and 20 minutes, respectively.

b) Participants and curriculum

Our sample included 180 first year students who were enrolled in the introductory physics course at the Faculty of Chemical Engineering and Technology in Zagreb, Croatia. The sample was divided into 6 subgroups whereby 3 subgroups received the control treatment and the remaining three subgroups received the experimental treatment.

In our sample, most of the students were 19-year olds and before their university education they had finished the eight-year primary and four-year secondary education. After graduating from the five-year study program at Faculty of Chemical Engineering and Technology, they can apply for jobs in industry or they can continue their education at PhD level. It should be noted that 73% of students in our sample were females and gender distribution was similar across all subgroups.

In Croatia, at the primary school level, students only learn the most basic facts about electrostatics such as learning to differentiate between positive and negative charges as well as a qualitative formulation of the Coulomb's law. At the secondary school level, this knowledge is broadened and deepened through student learning about the electric field, quantitative form of Coulomb's law as well as about electrostatic potential and work in the electrostatic field. However, Gauss's law is taught at the secondary school only at the level of conceptual explanations and simpler mathematics while at the university level students are applying the Gauss's law in many different (mainly quantitative) contexts due to its relatively complex mathematical representation. Generally, the curriculum of the introductory physics course at Faculty of Chemical Engineering and Technology can be characterized as a typical introductory physics course for scientists and engineers which follows standard textbooks such as Physics for Scientist and Engineers by Serway & Faughn (2006). It includes 2 hours of theoretical and 2 hours of practice sessions per week in both semesters of the first year of university. The theoretical sessions follow a traditional approach in which emphasis is on learning factual knowledge, whereas in practice sessions (Redish, 2003) the emphasis is on solving quantitative physics problems.

c) Treatment

Our study has been conducted in the spring semester of academic year 2016-2017 and it has been situated within the regular curriculum. Students from all subgroups received the same traditional theoretical sessions about electric field phenomena. Practice sessions for all students lasted in the same time (90 minutes) and were conducted by the same teaching assistant who is also the first author of this article. At the time of the experiment, the teaching assistant had five years of teaching experience.

In all subgroups we covered the same concepts related to electric field and Gauss's law.

In practice sessions, students from control subgroups received a typical traditional treatment characterized by solving of quantitative problems. Actually, the teaching assistant modeled the problem solving on blackboard and asked students to participate in discussion of most important aspects of the problem solving process. A brief description of quantitative problems that were solved and discussed in the control subgroups is given in Table I.

For the experimental subgroups, the traditional practice sessions have been enriched by visual presentation of analogies and extreme cases. So, the teaching assistant solved one quantitative problem less than in the control subgroups during the experimental treatment (Table I). The students from experimental subgroups were showed visualizations of the electric field for different geometric configurations of charges prior to solving quantitative problems. Firstly, the students were presented with a visualization of the electric field of an isolated positive/negative point charge and they were asked how the direction of field lines is related to the electric field vector. Then, they were asked to predict what happens if there is a two point charges as well as to relate this situation to the superposition principle. In last, students were showed an array of equidistant, positive charges that were fixed on a straight line (Figure 1) and they were asked to discuss the magnitude of electric force that acts on the individual charges. From symmetry considerations and superposition principle, students easily concluded the electric force on the central charge amounted to zero and that the largest force acted on the charges at the left and right end of the straight line. Since this one-dimensional configuration of positive charges proved to be easily comprehensible for most students, it was used as a cognitive anchor for developing understanding about more complex situations. In the next step, the teaching assistant showed a square frame with positive charges in its four vertices. Again, combination of symmetry considerations and principle of superposition helped the students to realize that the net electric field at center of the square was zero and the same conclusion has been drawn for an octagonal frame (Figure 1). In last, students were required to engage in extreme case reasoning in other words to predict what would happen if the number of vertices of the polygon tends to infinity. Most students realized that there is a uniformly charged (linear charge density λ=const) circle and the electric field at the center of the circle will be zero. Then, it was aimed to qualitatively discuss what happens if we move to an arbitrary point P located inside the circle, but right to the center of the circle (Figure 2). It was clear that the ratio of lengths l_1 and l_2 of circular arcs at opposite sides of point P is the same as the ratio of r_1 and r_2 in Figure 2. Thus, the ratio of net electric charges (which are proportional to length of the arcs) for these two circular arcs also amounts to r_1/r_2. By taking into account that the electric field is proportional to q/r^2, it follows that the electric field from the circular arc that is right from P has a larger magnitude in P than the electric field from the circular arc located left to P. In a nutshell, the field in P is different from zero because the effect of larger amount of charge on left circular arc is not exactly balanced by the smaller distance of right circular arc from point P. As a matter of fact, since $E_j = k\frac{q_j}{r_j^2}$, $j = \mathrm{L}, \mathrm{R}$ and $q_j = \lambda l_j = \lambda r_j \theta$ it follows:

$$E_L = k\frac{q_\mathrm{L}}{r_\mathrm{L}^2} = \frac{\lambda r_\mathrm{L}\theta}{r_\mathrm{L}^2}$$

$$E_R = k\frac{q_\mathrm{R}}{r_\mathrm{R}^2} = \frac{\lambda r_\mathrm{R}\theta}{r_\mathrm{R}^2}$$

$$\frac{E_L}{E_R} = \frac{\frac{\lambda r_L\theta}{r_L^2}}{\frac{\lambda r_R\theta}{r_R^2}} = \frac{r_R}{r_L}$$

Finally, the purpose was to explain what happens in the case of a three-dimensional object. Indeed, a sphere was considered (Figure 3) whose surface was uniformly charged (surface charge density σ=const). From symmetry considerations, it was easily come to the conclusion that both halves of the sphere have the same charge as well as average distance to the center of the sphere. Thus, on average the field vectors from the both semi-spheres have equal magnitude but opposite directions which means that the net field in the center of sphere is zero. In last, there was an attempt to explore the electric field outside the center of a surface charged sphere by using an approach analogous to the one we have used in the already considered as "charged circle". Thereby, an analogue to the plane angle θ subtended by a circular arc was the solid angle Ω (sphere) subtended by a part of spherical surface *S*. Then, for an arbitrary point inside the sphere, the superposition of net electric fields has been discussed due to parts of surfaces on opposite sides of that observed point. Indeed, since $q_j = \sigma S_j = \sigma r_j^2 \Omega,\ j = \mathrm{L}, \mathrm{R}$ it follows:

$$E_L = k\frac{q_\mathrm{L}}{r_\mathrm{L}^2} = \frac{\sigma r_\mathrm{L}^2 \Omega}{r_\mathrm{L}^2}$$

$$E_R = k\frac{q_\mathrm{R}}{r_\mathrm{R}^2} = \frac{\sigma r_\mathrm{R}^2 \Omega}{r_\mathrm{R}^2}$$

$$\frac{E_\mathrm{L}}{E_\mathrm{R}} = \frac{\frac{\sigma r_\mathrm{L}^2 \Omega}{r_\mathrm{L}^2}}{\frac{\sigma r_\mathrm{R}^2 \Omega}{r_\mathrm{R}^2}} = 1$$

Thus, superposition principle can be used to make the statement about zero field inside metal conductors which are more intuitive.

Only a brief, qualitative description has been provided for volume charged spheres. It was emphasized that volume charged spheres can be considered as extreme cases of surface charged spheres. As a matter of fact, the sphere can be considered for volume charged spheres as consisting of a large number of thin, concentric spherical shells of varying radii. If the field was considered at an arbitrary point P, there is exactly one shell X that passes through that point (Figure 3). The electric fields from the shells with radii greater than radius of shell X eliminate each other at P in a similar way as already described for surface charged spheres. However, the contributions of shells with radii smaller than radius of shell X do not eliminate each other. Symmetry arguments can be used to show that the center of charge for these inner shells is located at the center of the volume charged sphere which results with the fact that generally the electric field inside a volume charged sphere is not zero and increases with increasing distance from the center of the sphere.

Table 1. *A brief description of quantitative problems that were solved in the practice sessions. An asterisk denotes problems that were solved only in control subgroups.*

Problem 1	Calculating the coordinates of the location where total force on charge which is between two other fixed charges is zero.	Open-ended
Problem 2	Calculating electric field magnitude of the points inside and outside of a surface charged sphere.	Open-ended
Problem 3	Calculating the magnitude of electric field for points inside and outside of a volume charged sphere.	Open-ended
Problem 4	Calculating magnitude of the electric field at the point located at distance *r* from infinite cylindrical conductor.	Open-ended
*Problem 5	Calculating the surface charge density of a hollow sphere and magnitude of electric field at the surface of the sphere.	Open-ended

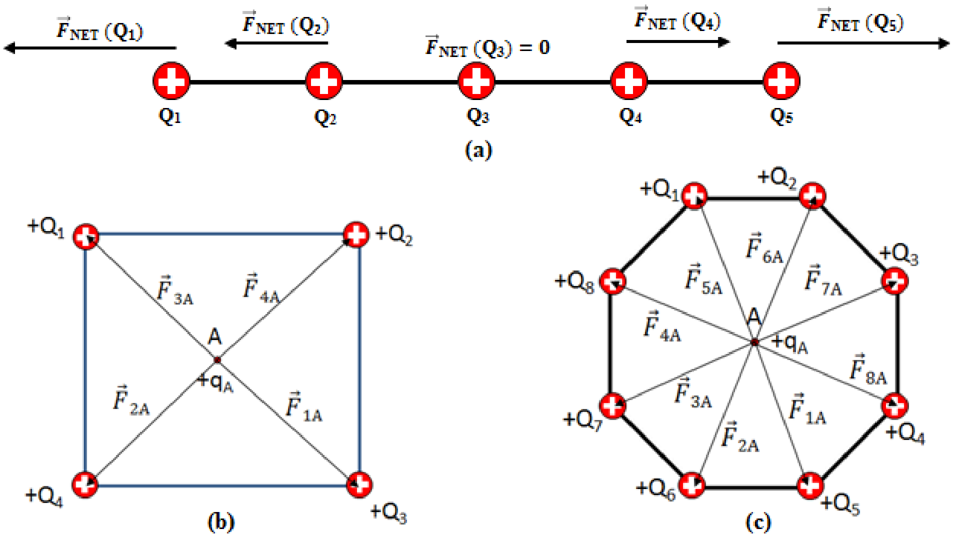


Fig. 1. At the center of the given configurations the net electric force is zero because all charges are equal and distances from charges to the center are equal.

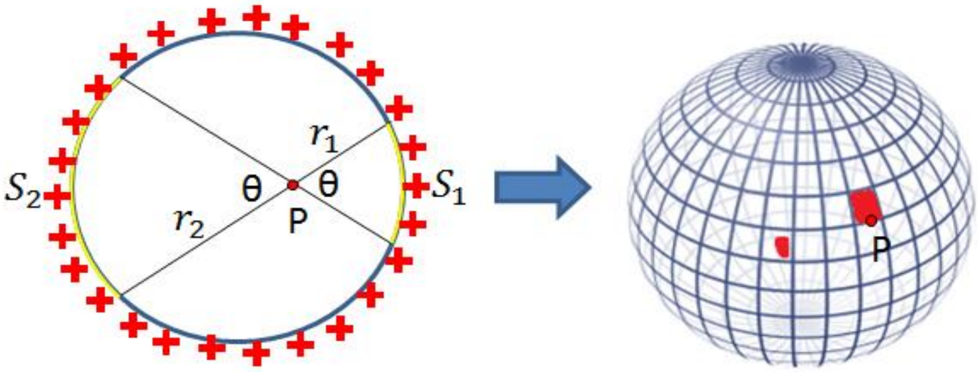


Fig. 2. Drawing analogies between a "charged circle", surfaced charged sphere and volume charged sphere

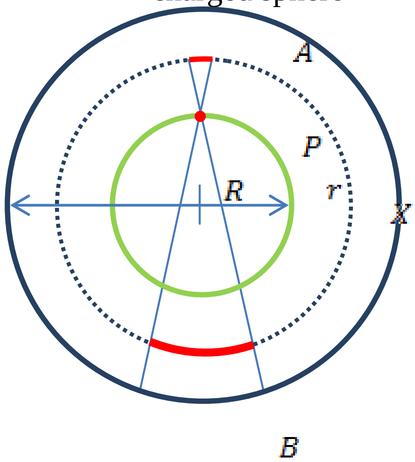


Fig. 3. Layout of three shells of different radii. Inner shell X is colored with green color.

d) Instruments

Two assessment instruments were created in order to compare the effects of our teaching treatments. Indeed, the threat to internal validity of our quasi-experiment was attempted to minimize by administering different instruments within the pretest and posttest contexts (Ary, Jacobs, Sorensen, & Razavieh, 2010). The purpose was to design assessment instruments that measure students' ability to solve qualitative and quantitative problems within the context of electrostatics and particularly Gauss's law. Thus, using knowledge for the purposes of problem solving is closely related to transfer of knowledge to situations that had not been explicitly considered within the teaching treatments (Marzano & Kendall, 2006).

The pretest consisted of five conceptual questions which were adapted from existing literature (Table 2). Barely, question 1 was adapted from the instrument created by Li & Singh (2017). In addition, we adapted questions 2, 3, 4, and 5 from the Conceptual Survey in Electricity and Magnetism (Maloney, O'Kuma, Hieggelke, & Heuvelen, 2001).

The posttest (Basic Understanding of Gauss's law Survey - BUGS) included 12 questions (Table 3). Questions 1 and 9 adapted from *College Physics* by Giambattista, Richardson, & Richardson (2007) and question 6 adapted from *Electromagnetism and structure of matter* by Lopac, Kulišić, Volovšek, & Dananić (1992).

The each of the correct answer was rewarded by one point at pretest as well as at posttest.

Table 2. *A brief description of pretest items.*

Item 1	Direction of electric field at a given point due to two point charges.	Multiple-choice
Item 2	What happens to electric charge that is brought to the surface of a metal sphere?	Multiple-choice
Item 3	How is the direction of electric field at a given point related to the appearance of field lines?	Multiple-choice
Item 4	What happens to magnitude and direction of net force at a given point if we add a third point charge?	Multiple-choice
Item 5	Influence of charge outside the metal sphere on charge located in the sphere's center.	Multiple-choice

Table 3. *A brief description of posttest items.*

Item 1a	What is the magnitude of the electric force on a charged sphere placed in a uniform electric field?	Open-ended
Item 1b	What is the direction of the electric force on a charged sphere placed in a uniform electric field?	Open-ended
Item 2	Comparing the magnitude of electric field at three points inside the uniformly surface charged, hollow cube.	Multiple-choice
Item 3	Predicting direction and magnitude of the net force at the center of a charged, infinite cylindrical conductor.	Multiple-choice
Item 4	Comparing the magnitude of electric field at three points inside a hollow, volume charged spherical shell.	Multiple-choice
Item 5	Can lightning sparks harm a person who is located in a metal cage?	Open-ended
Item 6a	Deriving the electric field expression for a point located at the surface of a volume charged sphere.	Open-ended
Item 6b	Deriving the electric field expression for a point located outside a volume charged sphere.	Open-ended

Item 6c	Deriving the electric field expression for a point located inside a volume charged sphere.	Open-ended
Item 7	Comparing the electric field at three given points for a body that consists of a non-conducting cylindrical shell in whose interior there is a cylindrical conductor.	Multiple-choice
Item 8	Predicting magnitude of electric field at different points of a surface charged metal disc with four symmetrically positioned cavities.	Multiple-choice
Item 9	Determining sign of the charge that is on the inner surface of a spherical shell if within the shell there is a small positively charged sphere.	Open-ended

The reliability of BUGS was calculated as 0.503 based on its Cronbach's alpha. This value can be considered as acceptable (Bowling, 2005, p. 397; McKagan, Perkins & Wieman, 2010). In addition, the average item difficulty index for the posttest was 0.46 which is close to the optimal value (Cohen & Swerdlik, 2009). Furthermore, the difficulty indices of most of the items ranged between the typically recommended boundaries of 0.2 and 0.8 (Kline, 2015). Indeed, there were only two items with difficulty indices outside the above mentioned boundaries - Item1b and Item 6c proved to be very difficult for our students, with difficulty indices of 0.19 and 0.07, respectively.

RESULTS

a) Pretest and posttest scores across subgroups

From Table 4, it can be concluded that students from experimental subgroups performed similarly to students from control subgroups on pretest. The average pretest score was highest for experimental subgroup 1 (EG1) and lowest for experimental subgroup 3 (EG 3). It should be noted that at the posttest, the score in the lowest performing experimental subgroup (EG3) was still higher than the score in the top performing control group (CG1).

Table 4. *Average pretest and posttest scores for experimental subgroups (EG) and control subgroups (CG) are provided. Theoretically, the scale for the pretest ranges from 0 to 5, and for the posttest it ranges from 0 to 12.*

	EG1	EG2	EG3	CG1	CG2	CG3
Pretest	2.0	1.68	1.39	1.97	1.93	1.77
SD	1.19	0.74	1.14	1.01	0.95	1.11
Posttest	6.55	6.52	5.91	5.26	4.93	3.87
SD	1.40	2.25	1.79	2.46	2.03	1.70

Since there can be observe a consistent effect in favor of experimental subgroups, it was decided to collapse the data for individual experimental and control subgroups. Thus, the data only analyzed on order to investigate differences between *two* broad groups – experimental group and control group instead of subsections.

b) Between-group differences in score distributions in the pretest and posttest contexts

Figure 3 shows the distribution of pretest scores in the control and experimental group. In both groups the most prevalent score at the pretest was two out of five points. Although, generally the shapes of the distributions were similar in both groups, there was a slightly higher incidence of low scores (0 or 1 points) in the experimental group. Indeed, the percentage of students who scored 2 points or lower on the pretest were 71% in the control group and 79 % in the experimental group.

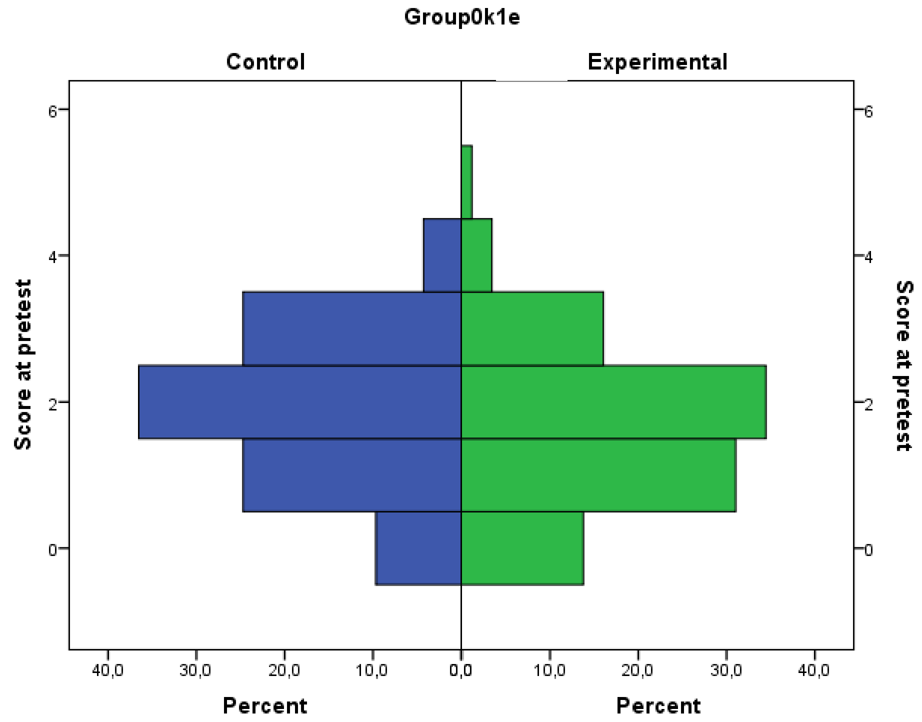


Fig. 3. Distribution of pretest scores in experimental and control group. Theoretically, the pretest scale ranges from 0 to 5.

The distribution of posttest scores for the experimental and control group is presented in Figure 4. From Figure 4, it is evident that the between-group differences at posttest are much more pronounced than the case at pretest.

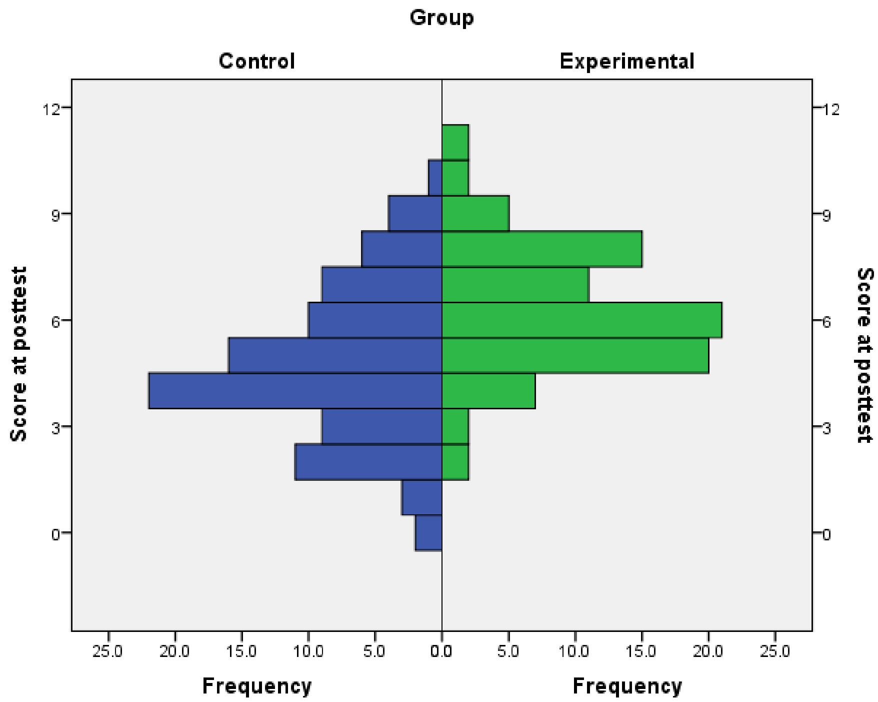


Fig. 4. Distribution of posttest scores in experimental and control group. Theoretically, the posttest scale ranges from 0 to 12.

From Figure 4, it is clear that within the experimental group the share of higher scores (i.e., > 7 points) is larger, and the share of very low scores (i.e., < 4 points) is smaller than in the control group. Indeed, the percentage of students who scored 2 points or lower was 17.2% in the control group at the posttest and 2.3% in the experimental group

Table 5 presents a summarized overview of students' achievement on pretest and posttest.

Table 5. *A summarized overview of average pretest and posttest scores provided for experimental and control groups. Theoretically, the scale for the pretest ranges from 0 to 5, and for the posttest it ranges from 0 to 12.*

	Pretest	Post-test
Control group	1.89	4.70
SD	1.02	2.17
Experimental group	1.68	6.30
SD	1.08	1.83

c) Investigating the significance of the observed between-group differences

The analysis of covariance (ANCOVA) was decided to use for investigating the statistical significance of the observed between-group differences on posttest which allow taking into account between-group differences on pretest (Field, 2009). Before running ANCOVA, the assumption of independence could be showed of the covariate (pretest score) and treatment ("group" as teaching treatment variable) was met ($t(178)=1.36$, $p=.17$). In addition, Q-Q plots showed that normality assumption approximately met for the control and experimental group (Howell, 2013). Since the Levene's test proved to be non-significant ($F(1,178)=2.38$, $p=.12$), there can be concluded that the homogeneity of variance assumption was met. Finally, it was also showed that the homogeneity of regression slopes assumption was not violated – the interaction between covariate and treatment variable proved to be non-significant ($F(1,176)=0.48$, $p=.49$)

ANCOVA results showed that there was a significant effect of teaching treatments on students' posttest scores after controlling for pretest scores ($F(1,177)=32.26$, $p<.001$, partial $\eta^2=.15$). A planned contrast showed that students from the experimental group significantly outperformed their peers from the control group ($t(177)=5.68$, $p<.001$, $r=.39$).

d) Item-level analyses

A summarized overview of between-group differences on individual posttest items is presented in Table 6.

Table 6. *Proportion of correct answers on individual posttest items is provided. Results are provided separately for control group (CG) and experimental group (EG).*

	Item 1a	Item 1b	Item 2	Item 3	Item 4	Item 5	Item 6a	Item 6b	Item 6c	Item 7	Item 8	Item 9
CG	.366	.129	.376	.613	.624	.462	.516	.398	.086	.366	.269	.495
SD	.484	.337	.487	.490	.487	.501	.502	.492	.282	.484	.446	.503
EG	.448	.253	.368	.920	.931	.816	.506	.391	.057	.655	.552	.402
SD	.500	.437	.485	.274	.255	.390	.503	.491	.234	.478	.500	.493

From Table 6 it is evident that experimental group students substantially outperformed than their peers from the control group on 7 out of 12 items and a remarkable difference (9%) in favor of control group students has been detected only on Item 9. In Item 9, students were expected to reason about the sign of the charge on the inner surface of a spherical shell in which is a small, negatively charged sphere. On the other hand, the largest difference in favor of experimental group students was detected for Item 5 (35%) which was supposed to assess students' understanding of the Faraday cage.

In Table 7 and Table 8, the most frequently made errors at pretest and posttest are presented.

Table 7. *Most frequent errors at the pretest.*

	Item 1	Item 2	Item 3	Item 4	Item 5
Pretest (overall)	A (47%)	D (26%)	A (12%)	D (27%)	E (48%)

Table 8. *Most frequent errors at the posttest. Results are provided separately for control group (CG) and experimental group (EG).*

	Item 1a	Item 1b	Item 2	Item 3	Item 4	Item 5
Post-test (CG)	Difficulties with the use of scientific notation (5%) Missing answers (50%)	Electric force direction is always equal to electric field direction (9%)	B (32%)	B (31%)	B (29%)	Students answered that it is possible but did not explain their answer in terms of physics (36%)
Post-test (EG)	Difficulties with use of scientific notation (16%) Missing answers (38%)	Electric force direction is always equal to electric field direction (16%)	B (57%)	B (6%)	B (4%)	Students answered that is possible but did not explain their answer in terms of physics (15%)
	Item 6a	**Item 6b**	**Item 6c**	**Item 7**	**Item 8**	**Item 9**
Post-test (CG)	Electric field is zero at the surface of a volume charged sphere (6%) Missing answers (26%)	Missing answers (26%)	The expression for electric field is the same inside and outside of the volume charged sphere (21%)	C (29%)	C (35%)	A positively charged sphere induces positive charge on the inner surface of the surrounding spherical shell (31%)
Post-test (EG)	Missing answers (24%)	Missing answers (25%)	The expression for electric field is the same inside and outside of the volume charged sphere (29%)	D (19%)	B (36%)	A positively charged sphere induces positive charge on the inner surface of the surrounding spherical shell (38%)

DISCUSSION

a) Overall between-group differences

The average score on the pretest was 1.74 out of 5 points. It should be noted that the pretest questions covered topics that are considered to be important for learning Gauss's law, such as superposition of electric field for different configurations of point charges (items 1 and 4) as well as qualitative ideas about distribution of charge on a conductor (Item 2), electric field lines (Item 3), and the concept of electrostatic shielding (Item 5). All these topics are included within the official high-school curriculum in Croatia which leads us to the conclusion that there is much place for improvement when it comes to developing conceptual understanding about electrostatics at the upper secondary school level in Croatia. The disappointingly low conceptual understanding of electrostatics at pretest could be at least partly accounted for the fact that physics instruction in Croatia typically follows traditional approach at all educational levels (Marušić & Sliško, 2012; Planinic, Ivanjek, & Susac, 2010).

The teaching treatments were only partly successful in promoting development of conceptual understanding about Gauss's law. Indeed, in the control subgroups the average proportion of correct answers at posttest was 39 %, and in experimental subgroups it was 53%. According to results of ANCOVA, the observed between-group difference can be considered as large and statistically significant (Pallant, 2010). Unlike students from the experimental subgroups, students from the control subgroups entered the problem solving session with less developed visual mental models about Gauss's law. Greca & Moreira (2000) suggested that developing of deep conceptual understanding about physics phenomena is often associated with development of corresponding internal visualizations of mechanisms that are at the mere heart of these phenomena. In experimental subgroups, students considered a sequence of increasingly complex configurations of charges and applied the superposition principle with the aim of reasoning about net electric field at arbitrary points. External visualizations were used and the segmenting principle was applied to prevent cognitive overload, i.e. gradually progressed from simple to more complex configurations of charges (Mayer & Moreno, 2003; Mayer, Hegarty, Mayer, & Campbell, 2005; Redish, 2003). Thereby, analogical and extreme case reasoning was used for the purposes of facilitating the transition from reasoning about net electric field inside a circle to reasoning about the net electric field inside a charged sphere. According to findings from earlier researches, usage of analogies and extreme cases helps students to create imaginable and intuitively grounded mental models of physical phenomena (Clement, 1988, 1993; Stephens & Clement, 2009, 2010; Zietsmann & Clement, 1997) which could explain the observed between-group differences.

The very low effectiveness of the traditional practice sessions can be explained based on results of the study by Kim and Pak who found that many students fail to overcome conceptual difficulties even after solving more than 1000 traditional problems (Kim & Pak, 2002). In addition, earlier researches showed that qualitative problems about Gauss's law which were included similar to the ones in BUGS prove to be extremely difficult for students in introductory physics courses (Aubrecht & Raduta, 2005; Guisasola et al., 2008; Maries et al., 2017; Pepper et al., 2010; Singh, 2006; Singh, 2005).

b) Between-group differences at the item-level

In the following lines, the most prominent between-group differences are going to be discussed on individual posttest items.

Item 9 was the only item for which a considerable between-group difference (9%) was detected in favor of control group students. In item 9 students were required to think about a metal spherical shell in center that was a positively charged, small sphere. Indeed, students were asked to determine the sign of the charge at inner surface of the spherical shell. In order to correctly solve item 9, students had to use their knowledge about charging by induction. Considering the fact that in the experimental subgroups, the focus was on reasoning about the net electric field for various configurations of charges, it is no surprise that in item 9 students from the experimental group did not outperform than their peers from the control group. If it is known that none of the two teaching interventions was explicitly focused on the charging by induction concept, then it is concluded that the better performance of the control group students at item 9 can be at least partly explained by their higher initial level of understanding about electrostatics, i.e. by their better results at the pretest.

The most prominent differences were observed for item 3, 4 and 5 in favor of students from experimental group. In items 3 and 4, students were required to think about the electric field at the center of a conducting cylindrical shell and at different points of a volume charged spherical shell, respectively. Within the experimental teaching intervention, students consistently used symmetry arguments to prove that electric field is zero in the center of objects of different shapes which can explain the results for item 3. In addition, students from the experimental group generally learned how to use the superposition principle to get an intuitive insight about electric field at some arbitrary point for a given configuration of charges which probably accounts for the observed between-group differences on item 4. Actually, the students from the control group were trained to predominantly rely on the mathematical formalism when thinking about electrostatics problems which proved to be relatively demanding within the context of item 4. On the other hand, many students from the experimental group probably approached the problem qualitatively by attempting to apply the superposition principle – on the line that extends through A (center) and B (point at outer surface), all charges produce the field of same direction in point B, which suggests that in point B the magnitude of the field is at its maximum. Generally, better achievement of experimental group students on items 3 and 4 is in line with the idea that visually rich models are often more effective than abstract models when it comes to solving qualitative problems (Greca & Moreira, 2000; Mešić, Hajder, Neumann, & Erceg, 2016; Nersessian, 2008). Since the visually rich models are easier activated in authentic contexts (Clement, 2008; Nersessian, 2008), it could also at least partly explain the superiority of experimental group students on item 5 which required the students to judge whether for a boy it would be safe to reside in a metal cage that is being struck by a lightning. It is interesting to note that on a similar item that was situated within a more formal context, students from the control group slightly outperformed their peers from the experimental group. In fact, the most students from the experimental group answered on item 2 that for a surface charged cube the electric field will be zero only in its center.

c) Students' misconceptions about electrical phenomena

First, the students' misconceptions are going to be discussed which observed at the pretest. Since the students from all subgroups were exposed to exactly the same curriculum before taking the pretest, the misconceptions identified at the pretest were similar across all subgroups. So, our discussion of misconceptions in the pretest context will be based on the data gathered across all subgroups.

In item 1 of the pretest, students were showed an equilateral triangle whereby in two vertices of the triangle that there were two point charges of equal magnitude and opposite sign. Students were asked to reason about the magnitude and direction of the net electric field at the third vertex of the triangle. Thereby, even 47% of the students answered that the net electric field has a zero magnitude at the given point. It follows that many students think that the electric fields of two point charges of equal magnitude and opposite sign eliminate each other at all points that are at equal distance from both charges. An alternative explanation is that some students believe that there must be a charge at a given point if the electric field at that point is to be non-zero (Li & Singh, 2017). In other words, some students think that electric field has a zero magnitude at all points in which there is no charge.

In Item 2 of the pretest, students were asked to predict what we will observe a few seconds after adding a small amount of charge to an arbitrary point P on the surface of a hollow, metal sphere. The 26% of the students answered for this item that the most of the charge will remain at point P and a smaller portion will spread over the surface of the sphere. Some of the reasoning can be characterized as reflecting to hybrid knowledge, i.e. knowledge that metal surfaces conduct charge combined with the intuitive belief with this point the largest initial concentration of charge will preserve its "status" even a few seconds after the experiment. This also indicates that many students are not aware of the order of magnitude of the time that has to pass until the establishment of electrostatic equilibrium. Generally, our findings for item 2 are in line with Maloney's (2001) conclusion that many students are confused about the ways in which charge distributes over a conductor.

In item 3, students were shown the electric field lines for a configuration of two point charges of opposite sign, whereby the negative point charge was located to the right side of the positive charge. They were required to reason about magnitude and direction of the net electric field at a point located on one of the field lines approximately above the negative point charge. On this item, 12% of the students answered that the electric field is directed from left to right. One possible explanation is that they overgeneralized their experiences with representations of uniform electric fields between plates of a capacitor where the electric field vector is always directed from the positively to the negatively charged plate. This finding is in line with Raduta's (2005) assertion that students have difficulties to relate electric field lines with the direction of the electric force vector.

On 4^{th} item of the pretest, students were shown three point charges. The charges Q_2 and Q_3 were positive and located on the y-axis whereas charge Q_1 was located on the x-axis and was at equal distance to the other two charges. Students were also provided the information that the force on Q_1 was directed along positive x-axis, and they were asked to predict what will happen with the net force on Q_1 after a new, positive charge Q is added to the x-axis. On this item, 27% of the students had the misconception that adding the charge Q will affect the action of charges Q_2 and Q_3, i.e. they believed that in calculating the net electric force the contributions from different point charges depend on each other. This result supports the assertion that students have many difficulties with the principle of superposition and calculation of the vector sum of the field (Li & Singh, 2017).

In item 5, students were shown an electrically neutral hollow sphere, whereby a positive point charge was located inside the sphere and another positive point charge was located outside the sphere. Students were required to reason about electrical interaction between these two point charges. On this item, 77.8% of the students chose options A or E reflecting to the belief that charge inside the sphere will act with a force on charge outside the sphere and vice versa. Thereby, the option E was the most frequently chosen option and it reflected the belief that the point charges experience electric forces of different magnitude. In the study by Maloney et al. (2001), the same item was correctly answered by only 16% of the students and the most common distracter was also option E.

Finally, students' difficulties are also going to be discussed with solving the posttest (Table VIII).

In Item 1a, students were required to calculate the magnitude of electric force acting on a charged sphere located in a uniform field, whereby information about amount of charge on the sphere and magnitude of electric field has been explicitly provided. Although the most of the students knew the relationship between electric force and electric field, some students proved to have difficulties with using the scientific notation and SI unit prefixes. So, these students failed to correctly calculate the product of amount of charge and magnitude of electric field. University students' difficulties with using exponents and scientific notation had been already reported in other studies (An & Wu, 2012; Heck & Van Gastel, 2006; Shepherd, Selden, & Selden, 2012).

When it comes to the direction of the electric force acting on the sphere (Item 1b), many students answered that is the same at the direction of the given electric field (CG: 9% and EG: 16%), despite the fact that the sphere was negatively charged.

In item 2, students were shown a surface charged cube and asked to compare the electric field at different points inside the cube. The most common error for both student groups (CG: 32% and EG: 57%) was the thought that electric field is zero at the center of the cube, but non-zero at other points inside the surface charged cube. Although it is attempted to provide an intuitive explanation in the experimental group for the fact that field is zero in all points inside a surface charged sphere, it seems that many students failed to transfer that reasoning to different geometrical shapes. An alternative explanation is the conceptual differences between the surface charged and volume charged bodies not been sufficiently discussed within our experimental treatment.

In Item 3, students were asked about the electric field in the center of a positively charged infinite cylindrical conductor. Whereas even 92% of the students from experimental group correctly solved this item, 31% of the students from the control group answered that the electric field at the center of the conductor will have a non-zero magnitude. The result for this item indicates that the experimental teaching treatment succeeded in developing the student habit to consider symmetry arguments when reasoning about the net field at the center of objects. Indeed, superposition principle had been used for finding the net field within the experimental treatment at the center of many geometric configurations of charges (line, square, octagon, circle and sphere).

In Item 4, students were asked to compare the electric fields at different points of a volume charged sphere with spherical cavity. Whereas even 93% of the students from the experimental group correctly solved this item, 29% of the students from the control group recognized that the field at the center of the cavity is zero but at the same time they believed that in the uniformly charged region the field will be the same at all points. In other words, it seems that some students think that a uniformly charged volume implicates a uniform field within that volume.

In Item 5, students were shown a photo depicting a boy in a metal cage being struck by lightning and asked to discuss whether the photo is genuine. Many students from the control (36%) and experimental group (15%) did not thoroughly explain their answer in terms of physics. Actually, many students did not provide a verbal explanation at all, particularly in the control group. It seems that mental models, which are mostly based on mathematical formalism, are relatively ineffective when it comes to generating rich, qualitative explanations which is in line with the findings by Greca and Moreira (1997).

In items 6a, 6b and 6c, students were required to derive the expression for electric field at three characteristic points of a volume charged sphere. Thereby, students had extreme difficulties with solving the volume integral and confused the expression for electric field with the Coulomb's law. Generally, earlier researches showed that students are having difficulties with applying integral calculus in the context of Gauss's law and electromagnetics in general (Bollen et al., 2015; Pepper et al., 2012).

In item 7, students were required to compare the electric field for a complex body consisting of a volume charged cylindrical shell in whose interior was a surface charged cylinder. In the control group, 29% of the students answered that the magnitude of the field is the highest on the central axis of the surface charged cylinder, and that it decreases as the radial distance from the center increases, becoming zero at the surface of the volume charged cylindrical shell. In other words, many students from the control group believed that the electric field at the surface of a non-conducting object has a zero magnitude. In the experimental group 19% of the students chose distracter D. They correctly recognized that the field inside the conductor is zero, but at the same time they did not realize that the electric field across the volume charged shell increases as we approach its surface. It is interesting to note that students from the experimental group were significantly less successful on item 7 than on the conceptually similar item 4. A possible explanation is that an intuitive approach to reasoning about the field of a volume charged *sphere* considered within the teaching treatment and for students it was easier to transfer the knowledge to the context of a thick spherical shell (item 4) than to the context of a cylindrical shell (Item 7).

In item 8, students were shown a surface charged metal disc with four symmetrically placed cavities. Students were required to reason about the electric field at the center of the disc as well as about the field in the cavities. Although the metal disc is thin, it is still a three-dimensional object which implicates that the field in its interior has to be zero and the field inside the cavities also has to be zero. In the experimental group, 36% of the students recognized that the electric field at the center of the disc is zero but at the same time they believed the fields at the center of the cavities to be non-zero. On the other hand, 35% of the students from the control group again did not recognize that the field inside a conductor has to be zero for the case of electrostatic equilibrium and they had the misconception that the electric field inside cavities should have a negative sign. The results for item 8 show that students from experimental group consistently outperformed their peers from the control group when it comes to reasoning about the electric field at the center of various objects.

In item 9, students were required to determine the sign of the charge at inner surface of a conducting spherical shell that its interior was a positively charged, smaller sphere. Students from the control group proved to be more successful in applying the concept of charging by induction for solving this qualitative problem.

d) Limitations of the study

Although the experimental treatment proved to be significantly more effective than the traditional treatment, results of the posttest indicate that none of the two teaching treatments succeeded to develop a high level of ability for solving qualitative and quantitative problems about Gauss's law in students. Particularly the performance on quantitative problems was very low in both groups.

It seems that there is much place for improvement within the experimental teaching intervention when it comes to differentiating the contexts of volume charged and surface charged bodies. Further, it seems that students need additional help to transfer their understanding about the field generated by charged spheres to fields generated by objects of different shapes.

When interpreting the findings from our study, one should take into account that these findings were obtained for an introductory physics course in which lectures follow a typically traditional format.

SUMMARY AND CONCLUSION

In this study, it was aimed to investigate whether enriching practice sessions with analogies and extreme cases can facilitate development of understanding about Gauss's law in university students. Indeed, it was aimed to find out whether reasoning about principle of superposition of electric field for relatively simple configurations of point charges can be effectively transferred to more complex geometric configurations and continuous distribution of charge.

The most important conclusions from our study are as follows:

- A step-by-step application of the superposition principle for increasingly complex configurations of charges facilitates the development of conceptual understanding about the Gauss's law.
- Combining analogical and extreme case reasoning can help to effectively relate the electric fields generated by a uniformly charged circle (very thin ring), a surface charged sphere and a volume charged sphere.
- Visually rich, analogical mental models are less inert in comparison with the mental models that predominantly include mathematical representations. They are also more effective for solving qualitative problems, particularly in contexts that are perceived by the students to be very different to contexts they explicitly encountered within instruction.

Suggestions

For purposes of developing students' understanding about Gauss's law, physics teachers are advised to invest additional efforts in relating the Gauss's law to the principle of superposition of electric field vectors. Thereby, it is recommended to gradually lead the students from reasoning about superposition of electric field vectors for a one-dimensional configuration of point charges to reasoning about the net electric field that results from a three-dimensional, continuous distribution of charges. The transition from discrete to continuous distributions of charges can be effectively accomplished by introducing a uniformly charged, very thin ring as an extreme case of a polygon (in which vertices are point charges) when the number of polygon's edges tends to infinity. Next, the electric field of a uniformly charged ring can be used as an analogical anchor for reasoning about the electric field of a surface charged spherical shell and the volume charged sphere can be introduced as an extreme case of the surface charged shell. In order to reduce the possibility of conceptual confusion, it is advisable to explicitly discuss with the students about similarities and differences in electric fields of the thin ring, surface charged spherical shell and volume charged sphere.

Although the presented teaching approach proved to be relatively effective in developing basic conceptual understanding about Gauss's law, there is still room for its improvement.

In future research, it would be useful to develop and evaluate strategies for helping the students to transfer their reasoning about charged spheres to charged objects of different shapes. Furthermore, it would be potentially interesting to explore whether students' understanding about the electric field inside volume charged spheres can be improved by introducing an analogy with the gravitational field inside the Earth.

Generally, the effectiveness of teaching about Gauss's law by combining analogies and extreme cases could be additionally explored through implementation of a mixed-research study which would also include student interviews.

REFERENCES

Adams, N. (2015). Bloom’s taxonomy of cognitive learning objectives. *Journal of Medical Library Association*, 103, 152–153. Doi: 10.3163/1536-5050.103.3.010

An, S., & Wu, Z. (2012). Enhancing mathematics teachers’ knowledge of students’ thinking from assessing and analyzing misconceptions in homework. *International Journal of Science and Mathematics Education*, 10, 717-753. Doi: 10.1007/s10763-011-9324-x

Ary, D., Jacobs, L. C., Sorensen, C., & Razavieh, A. (2010). *Introduction to Research in Education*. Belmont, CA: Wadsworth Cengage.

Aubrecht, G. J., & Raduta, C. (2005, September). Contrasts in student understanding of simple E&M questions in two countries. In *AIP Conference Proceedings*, 790 (1), 85-88. AIP: New York. Doi: 10.1063/1.2084707

Bagno, E., & Eylon, B. S. (1997). From problem solving to a knowledge structure: An example from the domain of electromagnetism. *American Journal of Physics*, 65, 726-736. Doi: 10.1119/1.18642

Bagno, E., Eylon, B. S., & Ganiel, U. (2000). From fragmented knowledge to a knowledge structure: Linking the domains of mechanics and electromagnetism. *American Journal of Physics*, 68 (1), 16-26. Doi: 10.1119/1.19515

Bloom, B. S., & Krathwohl, D. R. (1956). *Taxonomy of educational objectives: The classification of educational goals, by a committee of college and university examiners*. New York: Longmans.

Bollen, L., van Kampen, P., & De Cock, M. (2015). Students’ difficulties with vector calculus in electrodynamics. *Physical Review Physics Education Research*, 11, 020129. Doi: 10.1103/PhysRevPhysEducRes.13.019905

Bowling, A. (2005). Techniques of questionnaire design. In A. Bowling & S. Ebrahim (Eds.), *Handbook of health research methods: Investigation, measurement and analysis* (pp. 394-428). Maidenhead: Open University Press.

Clement, J. (1991). Nonformal reasoning in experts and in science students: The use of analogies, extreme cases, and physical intuition. *Informal Reasoning and Education*, 1, 345-362.

Clement, J. (1993). Using bridging analogies and anchoring intuitions to deal with students’ preconceptions in physics. *Journal of Research in Science Teaching*, 30, 1241-1257. Doi: 10.1002/tea.3660301007

Clement, J. (1988). Observed methods for generating analogies in scientific problem solving. *Cognitive Science*, 12, 563-586. Doi: 10.1207/s15516709cog1204_3

Clement, J. (2008). *Creative Model Construction in Scientists and Students: The Role of Imagery, Analogy, and Mental Simulation*. Dordrecht: Springer.

Cohen, R. J., & Swerdlik, M. (2009). *Psychological Assessment: An Introduction to Tests and Measurements*. Boston: McGraw-Hill Higher Education.

Demirci, N., & Çirkinoglu, A. (2004). Determining Students' Preconceptions/Misconceptions in Electricity and Magnetism Concepts. *Journal of Turkish science education*, 1(2), 51-54.

Einstein, A., & Infeld, L. (1938). *The Evolution of Physics*. London: The Scientific Book Club.

Field, A. (2009). *Discovering statistics using SPSS*. London: SAGE.

Giambattista, A., McCarthy Richardson, B., & Richardson, R. C. (2007). *College Physics, 2nd edition*. New York: McGraw Hill.

Greca, I. M., & Moreira, M. A. (1997). The kinds of mental representations models, propositions and images used by college physics students regarding the concept of field. *International Journal of Science Teaching*, 19, 711-724. Doi: 10.1080/0950069970190607

Greca, I. M., & Moreira, M. A. (2000). Mental models, conceptual models, and modelling. *International Journal of Science Education,* 22, 1-11. Doi: 10.1080/095006900289976
Grundmeier, T. A., Hansen, J., & Sousa, E. (2006). An exploration of definition and procedural fluency in integral calculus. *Primus,* 16, 178-191. Doi: 10.1080/10511970608984145
Guisasola, J., Almudí, J. M., Salinas, Zuza J. K., & Ceberio M. (2008). The Gauss's and Ampere laws: different laws but similar difficulties for student learning. *European Journal of Physics,* 29, 1005-1016. Doi:10.1088/0143-0807/29/5/013
Heck, A., & Van Gastel, L. (2006). Mathematics on the threshold. *International Journal of Mathematical Education in Science and Technology,* 37, 925-945. Doi: 10.1080/00207390600819003
Howell, D. (2013). *Statistical methods for psychology*. Belmont, CA: Cengage Learning.
Isvan, Z., & Singh, C. (2007, January). Improving student understanding of Coulomb's law and Gauss's law. In *AIP Conference Proceedings* (Vol. 883, No. 1, pp. 181-184). AIP: New York.
Jackson, J. D. (1999). *Classical electrodynamics - 3rd edition*. New York: Wiley.
Johnstone, A. H., & Al-Naeme, F. F. (1991). Room for scientific thought? *International Journal of Science Education,* 13, 187-192. Doi: 10.1080/0950069910130205
Kim, E., & Pak, S. (2002). Students do not overcome conceptual difficulties after solving 1000 traditional problems. *American Journal of Physics,* 70, 759-765. Doi: 10.1119/1.1484151
Kline, P. (2015). *A handbook of test construction (psychology revivals): introduction to psychometric design*. New York: Routledge.
Li, J., & Singh, C. (2017). Investigating and improving introductory physics students' understanding of the electric field and superposition principle. *European Journal of Physics,* 38, 055702. Doi: 10.1088/1361-6404/aa7618
Lin, J. W., & Chiu, M. H. (2017). Evaluating Multiple Analogical Representations from Students' Perceptions. In D. F. Treagust, Duit, R. & Fischer, H. E. (Eds), *Multiple Representations in Physics Education* (pp 71-91). Cham: Springer.
Lin, S. Y., Maries, A., & Singh, C. (2013). Student difficulties in translating between mathematical and graphical representations in introductory physics. In *AIP Conference Proceedings,* 1513 (1), 250-253). New York: AIP. Doi: 10.1063/1.4789699
Lopac, V., Kulišić, P., Volovšek, V., & Dananić, V. (1992). *Iz elektromagnetskih pojava i strukture tvari* [*Electromagnetism and structure of matter*]. Zagreb: Školska knjiga.
Maloney, D., O'Kuma, T.,Hieggelke, C., & Heuvelen, A. V. (2001). Surveying students' conceptual knowledge of electricity and magnetism. *American Journal of Physics,* 69, 12-23. Doi: 10.1119/1.1371296
Maries, A., Lin, S.-Y., & Singh, C. (2017). Challenges in designing appropriate scaffolding to improve students' representational consistency: The case of a Gauss's law problem. *Physical Review Physics Education Research,* 13, 020103. Doi: 10.1103/PhysRevPhysEducRes.13.020103
Marušić M., & Sliško, J. (2012). Influence of Three Different Methods of Teaching Physics on the Gain in Students' Development of Reasoning. *International Journal of Science Education,* 34, 301-326. Doi: 10.1080/09500693.2011.582522
Mayer, R. E., & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. *Educational Psychologist,* 38, 43-52. Doi: 10.1207/S15326985EP3801_6
Mayer, R. E., Hegarty, M., Mayer, S.,& Campbell, J., (2005). When static media promote active learning: Annotated illustrations versus narrated animations in multimedia instruction. *Journal of Experimental Psychology: Applied,* 11, 256-265. Doi: 10.1037/1076-898X.11.4.256

Maymoona, A. H., & Sulaiman, A. B. (2015). Rectifying Analogy-Based Instruction to Enhance Immediate and Postponed Science Achievement. *Journal of Turkish Science Education*, 12 (1), 3-17.
Marzano, R. J., & Kendall, J. S. (Eds.) (2006). *The new taxonomy of educational objectives*. Thousand Oaks: Corwin Press.
McKagan, S. B., Perkins, K. K., & Wieman,C. E. (2010). Design and validation of the quantum mechanics conceptual survey. *Physical Review Physics Education Research*, 6, 020121. Doi: 10.1103/PhysRevSTPER.6.020121
Mešić, V., Hajder, E., Neumann, K., & Erceg, N. (2016). Comparing different approaches to visualizing light waves: An experimental study on teaching wave optics. *Physical Review Physics Education Research*, 12, 010135. Doi: 10.1103/PhysRevPhysEducRes.12.010135
Moller, P., Kramer, B., & Bernd, B. (1991). Review: Electric fish. *BioScience*, 41 (11), 794-796. Doi: 10.2307/1311732
Nersessian, N. J. (1999). *Model-Based Reasoning in Scientific Discovery*. New York: Springer.
Nersessian, N. J. (2008). *Creating Scientific Concepts*. London: The MIT Press.
Pallant, J. (2010). *SPSS survival manual - 4th edition*. Berkshire: McGraw-Hill Education.
Pepper, R. E., Chasteen, S. V., Pollock, S. J., & Perkins, K. K. (2010, October). Our best juniors still struggle with Gauss's Law: Characterizing their difficulties. In *AIP Conference Proceedings*, 1289 (1), 245-248. New York: AIP. Doi: 10.1063/1.3515212
Pepper, R., Chasteen, E. S. V., Pollock,S. J., & Perkins, K. K (2012). Observations on Student Difficulties with Mathematics in Upper-Division Electricity and Magnetism. *Physical Review Special Topics- Physics Education Research*, 8, 010111. Doi: 10.1103/PhysRevSTPER.8.010111
Planinic, M., Ivanjek, L., & Susac, A.(2010). Rasch model based analysis of the Force Concept Inventory. *Physical Review Physics Education Research*, 6, 010103. Doi: 10.1103/PhysRevSTPER.6.010103
Podolefsky, N. S., & Finkelstein, N. D. (2006). Use of analogy in learning physics: The role of representations. *Physical Review Physics Education Research*, 2, 020101. Doi: 10.1103/PhysRevSTPER.2.020101
Raduta, C. (2005). General students' misconceptions related to Electricity and Magnetism. *arXiv preprint physics/0503132*.
Redish, E. F. (2003). *Teaching Physics With the Physics Suite*. New York: Wiley.
Serway, R. A., & Faughn, J. S. (2006). *Holt Physics*. Austin: Holt, Rinehart and Winston.
Sevim, S. (2013). Promoting Conceptual Change in Science Which is More Effective: Conceptual Change Text or Analogy? Journal of Turkish Science Education, 10 (3), 24-36.
Shepherd, M. D., Selden, A., & Selden, J. (2012). University Students' Reading of Their First-Year Mathematics Textbooks. *Mathematical Thinking and Learning*, 14, 226-256. Doi: 10.1080/10986065.2012.682959
Silva, C. C. (2007). The role of models and analogies in the electromagnetic theory: a historical case study. *Science & Education*, 16, 835–848. Doi: 10.1007/s11191-006-9008-z
Singh, C. (2005). Student understanding of Symmetry and Gauss's law. In *AIP Conference Proceedings*, 790 (1), 65-68. New York: AIP. Doi: 10.1063/1.2084702
Singh, C. (2006). Student understanding of symmetry and Gauss's law of electricity. *American Journal of Physics*, 74, 923–936. Doi: 10.1119/1.2238883
Sorden, S. D. (2005). A Cognitive Approach to Instructional Design for Multimedia Learning. *Informing Science Journal*, 8, 264-279.

Stephens, A. L., & Clement, J. J. (2009). Extreme case reasoning and model based learning in experts and students. *In Proceedings of the 2009 Annual Meeting of the National Association for Research in Science Teaching*, 17-21 April, *Garden Grove, CA.*

Stephens, A. L., & Clement, J. J. (2010). Documenting the use of expert scientific reasoning processes by high school physics students. *Physical Review Physics Education Research,* 6, 020122. Doi: 10.1103/PhysRevSTPER.6.020122

Stewart, J. V. (2001). *Intermediate Electromagnetic Theory*. Singapore: World Scientific.

Sweller, J., Van Merrienboer, J. J., & Paas, F. G. (1998). Cognitive architecture and instructional design. *Educational Psychology Review,* 10, 251-296. Doi: 10.1023/A:1022193728205

Traxler, A. L., Black, K. E., & Thompson, J. R. (2007). Students' use of symmetry with Gauss's law. In *AIP Conference Proceedings*, 883 (1), 173-176. New York: AIP. Doi: 10.1063/1.2508720

Van Merrienboer, J. J., & Sweller, J. (2005). Cognitive load theory and complex learning: Recent developments and future directions. *Educational Psychology Review,* 17, 147-177. Doi: 10.1007/s

Viegas, J. (2007). *Critical Perspectives on Natural Disasters*. New York: The Rosen Publishing Group.

Viennot, L. & Rainson, S. (1992). Students' reasoning about the superposition of electric fields. *International Journal of Science Education,* 14, 475-487. Doi: 10.1080/0950069920140409

Zietsman, A., & Clement J., (1997). The role of extreme case reasoning in instruction for conceptual change. *Journal of Learning Sciences,* 6, 61-89. Doi: 10.1207/s15327809jls0601_4

TÜRK FEN EĞİTİMİ DERGİSİ
Yıl 15, Sayı 3, Eylül 2018

Journal of
TURKISH SCIENCE EDUCATION
Volume 15, Issue 3, September 2018

http://www.tused.org

Examining Argumentation Skills of Preservice Science Teachers in Terms of their Critical Thinking and Content Knowledge Levels: An Example Using GMOs*

Ümit DEMİRAL[1], Salih ÇEPNİ[2]

[1] Assist. Prof. Dr., Ahi Evran University, Kırşehir-TURKEY, ORCID ID: 0000-0003-3873-7019
[2] Prof. Dr. Uludag University, Bursa-TURKEY
* This study is a part of the dissertation entitled "Investigating Argumentation Skills of Pre-service Science Teachers in a Socio-scientific Issue in terms of Critical Thinking and Knowledge Level: GM Foods Case"

Received: 20.07.2018 **Revised:** 20.09.2018 **Accepted:** 30.09.2018

The original language of article is English (v.15, n.3, September 2018, pp.128-151, doi: 10.12973/tused.10241a)

ABSTRACT

The aim of this study was to examine the argumentation skills of preservice science teachers on genetically modified foods during an argumentation process. Within case study research methodology, this study was carried out with 20 preservice science teachers identified through convenience sample from science education department. Knowledge Test for GMOs, Watson-Glaser Critical Thinking Appraisal and semi-structured interview questions were used to collect data. Findings showed that the groups with high level genetically modified food knowledge tended to use more qualified rebuttal and evidence. On the other hand, the groups with high level critical thinking skills were apt to exploit more qualified warrant, counter-argument, rebuttal and evidence. The research findings revealed that knowledge level and critical thinking skills are influential on argumentation skills. It was concluded that content knowledge is associated with self-efficacy and motivation in argumentation. However, critical thinking skills are associated with focusing, open-mindedness, understanding opposing ideas, and finding missing parts. In the light of this information, some suggestions was made for the development of knowledge and critical thinking skills for policy makers and educational scientists who have designed a teacher training program.

Keywords: Preservice Science Teachers, Socio-Scientific Issues, Genetically Modified Organisms, Content Knowledge, Critical Thinking Skills, Argumentation Skills.

INTRODUCTION

In many countries' science curriculum, students are targeted to be educated as "scientifically literate individuals" (Barrue & Albe, 2013). In the Turkish national science curriculum, which aims to develop students' science literacy, scientifically literate individuals are defined as follows: Scientifically literate individuals are individuals who research, inquire, have critical thinking skills, make decisions through logical reasoning, solve problems, defend their own opinions, self-confident, open to co-operation, entrepreneurs and life-long learners with an awareness of sustainable development (MNE, 2017). In the last quarter of the 21st

Corresponding author e-mail: udemiraltr@gmail.com
© ISSN:1304-6020

century in particular, emergent socio-scientific issues (SSIs) such as global warming, cloning, genetically modified organisms (GMOs) and organ transplantation have strengthened the links between science and society. Thus, this issues have been included in the science curriculum as a part of the movement to reform the curriculum and promote the development of scientifically literate individuals.

Teachers have an important role in educating individuals. In schools, the role of science teachers is to develop students' scientific literacy and help them to gain conceptual understanding (Kilinc, Kelly, Eroglu, Demiral, Kartal, Sonmez & Demirbag, 2017). As stated by Sadler and Zeidler (2009), science teachers should improve the learning environment by introducing students controversial scientific ideas and helping them to associate their knowledge with daily-life activities. Furthermore, teachers can assist students' understanding of scientific concepts by enabling them to experience scientific activities carried out in the classroom, which will eventually contribute to the development of scientifically literate learners (Moore, 2008). Although the use of argumentation is recommended in the teaching of SSIs, which has recently been at the higher rank on the agenda of many countries, teaching an SSI is often carried out in the form of lectures or superficial discussions in science undergraduate programs (Kilinc, Demiral & Kartal, 2017). Some studies considered argumentation as a teaching method (Zohar & Nemet, 2002) and other studies examined its effects on cognitive development (Eskin & Ogan-Bekiroglu, 2013).

For preservice teachers, the skills of argumentation are also very important. However, there have only been a small number of studies conducted with preservice science teachers (PSTs) in order to improve their argumentation skills with regard to SSIs. The results of these studies indicated that the PSTs' argumentation skills depends on a number of factors such as the nature of science, content knowledge and epistemology (Sadler & Fowler, 2006; Khishfe, Alshaya, Boujaoude, Mansour & Alrudiyan, 2017; Liu & Roehrig, 2017). On the other hand, these studies did not explain how the PSTs' argumentation skills were influenced by their content knowledge and critical thinking skills, which are likely to be related to the quality of any discussion. Therefore, the purpose of the present study was to understand the nature of the relationship between the PSTs' argumentation skills and their content knowledge and critical thinking skills with regard to one SSI (GMOs). In the following section, theoretical framework of the study was presented at first. Next, some background information about these skills was presented in three sub-sections. The relation between the PSTs' argumentation skills and their content knowledge were explained in the first sub-section. The relationship between the PSTs' argumentation skills and their critical thinking was explained in the second sub-section. In the final sub-section, focus was narrowed on the current findings about the relations between argumentation skills, content knowledge and critical thinking in the context of SSIs. The theoretical framework informs our terminology, methods, analysis and interpretations.

Theoretical framework

Social constructivism is an approach that emphasizes the importance of individual's social interactions in acquiring skills and knowledge (Vygotsky, 1978). According to this theory, the process of argumentation is useful for gaining a deeper conceptual understanding of a specific subject or understanding other aspects of that subject, whether it is carried out in small or large groups (Schunk, 2012). Dialogical communication is indispensable for argumentation and teaching (Kilinc, Demiral & Kartal, 2017). Vygotsky (1978) suggested that an individual's interaction with their environment contributes to their success in learning. The experiences of a person in a learning situation can affect the outcome to a great extent (Schunk, 2012). Learning and thinking also arise in the context of beliefs about cognition, which is a process that varies as a function of personal, social and cultural factors related to an individual. The beliefs that the individual possesses are also closely related to such factors as self-efficacy (Bandura, 1986) and motivation (Sivan, 1986). That is, individuals who believe that their talents are fixed and unchanging can easily lose heart when they encounter difficulties in daily life because they think that there is not much that they can do to change the situation (Schunk, 2012). Such loss of courage leads to low self-efficacy (Bandura, 1986).

On the other hand, individuals, who believe that they have control over their learning abilities, find it hard to give up when they encounter a problem and instead of changing their strategies, consult additional sources of information or engage in forms of self-regulation (Bandura, 1997). Individuals with high self-efficacy expend more effort in countering arguments and are more likely to respond when they have the necessary skills (Aydeniz & Özdilek, 2016). As can be seen clearly here, self-efficacy affects the efforts made and commitment to advocating points of views during the process of argumentation. In addition, Bandura (1988) defined motivation as a target-directed behavior that is actuated and sustained by anticipating and predicting the outcomes of other people's actions and their self-efficacy in realizing those actions. According to Bandura (1988), experience is very important in the manifestation of these behaviors because if an individual has not previously performed the behavior to be learned, she/he doubts her/himself and this prevents the use of previously-acquired skills. As a result, the individual's motivation decreases. When an individual enters the learning environment, his/her sense of self-efficacy with regard to learning is based on previous experiences, personality traits and social support mechanisms (Schunk, 2012). Argumentation skills are not only justification, rebuttal or evidence but also they involve rather complicated mechanisms such as presenting a claim, justifying claims, being aware of counterarguments, rebuttal of counter arguments, and using evidence (Lin & Mintzes, 2010; Sandoval & Millwood, 2005). To use these skills in the argumentation process, the motivation for the subject should be high (Trend, 2009). Self-efficacy is also important because it can affect motivation, cognition, emotional processes, and ultimately the behavior of individuals (Erika & Prahani, 2017).

Background Information

Argumentation Skills and Content Knowledge

Argumentation skills can be defined as skills in which knowledge is used to justify a decision through the use of scientific, logical and creative thinking (Foong & Daniel, 2013). In the literature, one of the predictive factors for argumentation skills was reported to be cognitive ability. Lin and Mintzes (2010) and von Aufschnaiter, Erduran, Osborne and Simon (2008) studied the connection between argumentation skills, and 'preliminary information' and 'experiences', which are considered to be factors of cognitive ability. These researchers ascertained that students who were engaged in argumentation used their former experiences and knowledge in the process and those such activities strengthened their existing knowledge and enabled them to evaluate other students' levels of scientific knowledge. By drawing attention to the scientific knowledge of students, Schunk (2012) and Snyder and Lopez (2009) claimed that students draw on their former knowledge, general abilities, motivations and self-confidence when engaged in an argument.

Some researchers have observed relationship between content knowledge and argumentation. For instance, Sadler and Zeidler (2005b) reported that the students with a high level of knowledge are better at asserting more well-grounded justifications than students with a low level of knowledge. In another study, Sadler and Fowler (2006) reached the conclusion that students with a high level of content knowledge generally presented more detailed justifications in comparison to students with a low level of knowledge. Furthermore, as stated by Zohar and Nemet (2002) and Eskin and Ogan-Bekiroglu (2013), there was a significant increase in students' knowledge levels if argumentation was used as a teaching method in the classroom.

Argumentation Skills and Critical Thinking Skills

Examining the definitions of the argumentation and critical thinking skills in the literature is useful in revealing the relation between critical thinking and argumentation. Paul and Elder (2001) defined critical thinking as the kind of cognitive ability used in deciding complicated situations. Similarly, Kuhn (1999) defined critical thinking as a cognitive ability used for solving ill-structured problems. In an argumentation process, critical thinking is considered to be a cognitive thinking mechanism used for decision-making and problem solving. Analyzing the relationship between argumentation and critical thinking, it was identified that a critical thinker often deploys critical thinking skills such as using evidence, reasoning, resisting authority, using their own opinions to evaluate knowledge, evaluating the validity and reliability of claims and providing evidence based on the claims (Voss & Dyke, 2001). By using critical thinking ability, an individual can display the following skills during an argument: First, individual can critically question socially-accepted claims, reinforcing them with supporting ideas or refuting them with evidence (Zohar & Nemet, 2002) while taking personal responsibility for this in a motivated way (Braund, Scholtz, Sadeck, & Koopman, 2013). Second, the individual can pay attention to the arguments being made, be eager to respond to group members' comments, and make a contribution towards integrating new evidence into existing knowledge (Driver, Newton & Osborne, 2000). Third, the individual can emphasize the frequently changing nature of scientific knowledge by using new evidence. Finally, the individual can test and evaluate assertions and theories of argumentation (Braund et al. 2013).

In addition to these skills, critical thinking allows individuals to develop valid arguments by using information with strong evidence that involve assumptions, concepts and phenomena. Moreover, critical thinking provides the opportunity for individuals to critically evaluate the strength of the arguments. In a high-quality argumentation process, critical thinking enables individuals to identify the validity of concepts and thoroughly understand the cause and effect relations between these concepts (Saracaloglu, Aktamis & Delioglu, 2011). During the process of argumentation, critical thinking allows cognitive abilities to be used in a more effective, structured and analytical way in order to justify assertions.

Researchers (Jimenez-Aleixandre, Rodriguez & Duschl, 2000; Öğreten & Uluçınar-Sağır, 2014) focused on relationship between argumentation and critical thinking. Jimenez-Aleixandre, Rodriguez and Duschl (2000) have emphasized the important role of critical thinking in defining evidence in addition to choosing, using and evaluating it. According to these researchers, critical thinkers cares about their warrants, which depend on processes of evaluation, judgment, and the situation being discussed while evaluating claims and judging or designing alternative situations. Thus, argumentation facilitates the construction of knowledge in the mind, or, in other words, argumentation acts as a mechanism that both creates and deploys knowledge (Ogan-Bekiroglu & Eskin, 2012). If an individual is able to construct an argument, she/he can also understand the meaning of a concept. Therefore, argumentation is an inseparable part of the thinking process (Kuhn, 1991). Argumentation is a manifestation of thinking, developing, and analyzing arguments can pave the way for new arguments to be made (Ogan-Bekiroglu & Eskin, 2012).

The Relationship between Critical Thinking Skills, Content Knowledge and Argumentation Skills in the context of SSIs

There are some specific features of being a good citizen in a democratic society. One of those features is having critical thinking skills and developing independent ideas (Jimenez-

Aleixandre, & Puig, 2012). Initiating discussions about current social issues such as GMOs (Walker & Zeidler, 2007), the choice of energy sources and climate change (Schweizer & Kelly, 2005) or the use of mobile phones and base stations (Albe & Simonneaux, 2005) can be used in supporting efforts to educate students to be sensitive citizens. SSIs are included in science education programs to support students in becoming the good citizens of the future (Barrue & Albe, 2013). They provide the opportunity for students to develop their own personal ideas and can create a platform for discussion through argumentation in the classroom because of the inherent dilemmas involved in them (Albe, 2008). Studying SSIs also contributes to the development of students' critical thinking skills (Freeley & Steinberg, 2013) and their content knowledge (Mason & Scirica, 2006). Hence, by discussing current social issues in classrooms using argumentation students have the opportunity to use and develop thinking skills including analysis, deduction, explanation, evaluation, interpretation and self-regulation (Facione, 1991). Furthermore, discussing an SSI through argumentation also provides an opportunity for educators to train students who are able to research facts, be open-minded, analytical, systematic and fair, and rely on their own reasoning (Zeidler & Nichols, 2009), while also improving students' content knowledge (Sadler & Donnelly, 2006).

Argumentation can be defined as a process of constructing appropriate reasoning in which individuals are able to assert claims through using logical justifications which can be linked to data, and it has an important role in science education (Driver et al. 2000). However, SSIs, which are controversial issues, require not only scientific but also moral justifications to be made in order for the dilemmas, they raise relating to science and technology to be resolved (Zeidler & Nichols, 2009). These issues enhance students' active participation and require justifications to be made by using scientific data as evidence (Sadler & Zeidler, 2005a). Since studying SSIs develops students' argumentation skills, their inclusion recommended in science education programs and classrooms (Topcu, Sadler & Yilmaz-Tuzun, 2010). Turkey is one of the countries which now including SSIs in science education programs.

This current study contributes the literature on the PSTs' argumentation skills by examining the limitations that was discussed in the previous paragraph. The study is crucial for curricula development, policymakers, and teachers and also for the future of teacher training programs. So, many countries have included SSIs in science education programs in the last decade. Therefore, the aim of this study was to examine the PSTs' argumentation skills with regard to GMOs during a specific process of argumentation. For this reason, we defined the main research problem and sub- problems as follows:

1. How do PSTs' argumentation skills with regard to GMOs differ in terms of their critical thinking skills and content knowledge?

(1a.) What are the differences between the argumentation skills of the PSTs with high-level critical thinking skills and low-level content knowledge, and those with low-level critical thinking skills and low-level content knowledge?

(1b.) What are the differences between the argumentation skills of the PSTs with low-level critical thinking skills and high-level content knowledge, and those with low-level critical thinking skills and low-level content knowledge?

(1c.) What are the differences between the argumentation skills of the PSTs with high-level critical thinking skills and high-level content knowledge, and those with high-level critical thinking skills and low-level content knowledge?

(1d.) What are the differences between the argumentation skills of the PSTs with high-level critical thinking skills and high-level content knowledge, and those with low-level critical thinking skills and high-level content knowledge?

METHODS

a) Study Design

In this study, it was aimed to investigate three variables in the context of SSIs: content knowledge with regard to GMOs, critical thinking skills and argumentation skills.

In order to elicit arguments as a means of empirically comparing argumentation skills, participants engaged in a process of argumentation about an SSI and explicitly asked them to formulate warrants, counter-arguments, rebuttals and evidence in response to a series of related issues. This technique is consistent with other more general investigations of argumentation skills (Acar, 2016 Lin & Mintzes, 2010; Sadler & Zeidler, 2005b; Venville & Dawson, 2010).

In the study, the holistic multiple case study which is a form of qualitative research that is one of the special case study models was adopted to analyze and compare the relationships among the variables (Yin, 2013). In this study, groups with different levels of content knowledge and critical thinking skills are created and each situation is handled holistically. Then the groups are compared.

b) The Study Group

This study was performed with 20 PSTs studying at a science education department. The study group was selected by convenience sampling, one of the random sampling methods used in the purposive sampling model.

For the selection of the teacher candidates taking part in the argumentation, this process was followed:

1. A Knowledge Test about GMOs (KT-GMOs) and the Watson Glaser Critical Thinking Appraisal (WG-CTA) were administered to 209 PSTs.
2. Using both test results, PSTs were assigned from highest to lowest in terms of ranking. To specify the groups, the 27% lower-27% upper formula was applied.

Participants were separated into high and low levels according to their test scores. To decide how to separate the PSTs into high and low level groups, literature was examined about knowledge and critical thinking skills (Sadler, 2003; Sadler et al. 2004). There are five preservice teachers with low-level CT and KT-GMOs in Group-A, five preservice teachers with high-level CT and low-level KT-GMOs in Group-B, five preservice teachers with low-level CT and high-level KT-GMOs in Group-C, five preservice teachers with high-level CT and KT-GMOs in Group-D.

The pseudonyms, gender, grade level and ages of the PSTs selected for the argumentation session as a result of this grouping are given in Table 1 below.

Table 1. *The characteristics of PSTs with different levels of critical thinking skills and GMO knowledge*

Groups	Level	PSTs	Gender	Grade level	Age	Knowledge Test Score	Sub-dimension of critical thinking: Inference	Recognition of assumptions	Deduction	Interpretation	Evaluation of arguments	Critical Thinking Test Score
A	CT (Low) KT-GMOs (Low)	PST-1	M	3	23	8	5	8	7	10	1	31
		PST-2	F	1	19	8	3	5	5	7	2	22
		PST-3	F	2	20	7	4	7	6	11	2	30
		PST-4	F	2	22	7	5	8	8	12	2	35
		PST-5	F	1	20	8	9	6	5	7	1	28
B	CT (High) KT-GMOs (Low)	PST-6	F	1	18	5	8	13	12	18	8	59
		PST-7	M	1	18	6	12	12	7	19	6	56
		PST-8	F	2	20	8	9	10	11	18	7	55
		PST-9	F	1	18	5	7	11	12	18	5	53
		PST-10	F	2	20	8	10	10	13	16	6	55
C	CT (Low) KT-GMOs (High)	PST-11	M	4	22	16	4	4	8	11	6	33
		PST-12	F	4	23	15	5	8	6	11	6	36
		PST-13	F	2	21	15	8	8	3	8	8	29
		PST-14	F	4	23	16	2	8	5	9	3	27
		PST-15	F	4	21	15	5	7	7	12	6	37
D	CT (High) KT-GMOs (High)	PST-16	M	4	22	19	8	10	13	17	6	54
		PST-17	F	4	25	15	13	9	12	18	8	60
		PST-18	M	4	22	17	9	11	12	18	7	57
		PST-19	F	4	21	15	11	9	12	18	6	56
		PST-20	F	4	22	19	11	12	12	19	7	61

c) Data Collection Tools

The following were used as data collection tools: (1) Watson-Glaser Critical Thinking Appraisal (WG-CTA), (2) Knowledge Test about GMOs (KT-GMOs) and (3) the 'Help Somalia' scenario including semi-structured interview questions (Appendix A-B).

Watson-Glaser Critical Thinking Appraisal Test Form-Ym (Wg-Cta)

The WG-CTA test was adapted to Turkish by Çıkrıkçı (1993). She was contacted her via email and written mail and received ethical and legal permission. After the necessary legal permissions had received, the test was implemented. From the results obtained from a pilot application on 210 science teachers, the lower 27% and upper 27% groups were formed and the significance of differences for each item and subscales was analyzed by t-test analysis. In addition, item-total test correlations were used to examine the reliability of the scales and the Kuder-Richardson Formula 20 (KR-20) was used to examine the reliability of the entire scale. At the end of the validity and reliability testing of the WG-CTA, it was decided to remove 23 items from the test. As a result of the pilot study, the critical thinking test was made ready for the actual application in such a way that the *inference* dimension of the test consisted of 16 items, the dimension of *recognition of assumptions* consisted of 14 items, the *deduction* dimension consisted of 16 items, the *interpretation* dimension consisted of 21 items and the *evaluation of arguments* dimension consisted of 10 items. As a general conclusion, it was decided to restructure the WG-CTA and continue the original application with 77 items. The KR-20 value of the test, which was ready for immediate application, was calculated to be 0.732 in the final pilot study.

Knowledge Test for GMOs (KT-GMOs)

Gaskell, Allansdottir, Allum, Corchero, Fischler, Hampel, Jackson, Kronberger, Mejlgaard, Gemma, Schreiner, Torgerseni and Wagner (2006), Sjöberg (2004) and Sönmez and Kılınç (2012) were used in the process of forming a material pool for this measurement tool. In this test, the options for each question are "I don't know", "right" and "wrong". In order to use the scale in the study, permission was taken from the researchers via e-mail.

The draft scale consisting of 30 questions was applied to 210 university students. According to the results obtained in the pilot study, groups were formed from the lower 27% and upper 27% according to the total KT-GMOs score and the significance of the differences for each question item was analyzed with t-test analysis. In addition to this, the item total correlations were examined for the reliability of the scale items and the KR-20 values for the overall reliability of the test. There was a significant difference according to the level difference between the knowledge of the PSTs in the t-test analysis for the 27% sub-group and the 27% upper-group item mean scores according to the total score order of the respondents to the KT-GMOs [$t_{100}=25.261$, $p<.05$]. In other words, the test developed to measure the knowledge of PSTs about GMOs distinguished preservice teachers who knew about the subject from who did not. The item-total correlations ranged for all the items in the test from -0.230 to 0.488 and the t-values were significant ($p <.05$). Following the statistical process in the pilot application, 10 items were removed from the test and it was decided to continue the actual application with 20 items. The KR-20 value was calculated to be 0.735 in the final pilot application before the actual application.

"Help Somalia" Scenario and Semi-Structured Interview Questions

The group discussion method was used to examine the argumentation skills of PSTs with regard to the issue of GMOs. During the creation of the scenario (Appendix-A) and the scenario-related discussion questions (Appendix-B), we considered the problems and sub-problems, the nature of the research and the work done (Toulmin, 1958; Kuhn, 1991; Sadler, 2003; Lin & Mintzes, 2010; Topcu et al. 2010). As a data collection tool, the scenario was formulated to be the one which people are often confronted and people tend to use their experiences to find more than one way to solve open-ended problems as in real life. For this reason, they use critical thinking skills when solving a problem (Carvalho, Fiuza, Conboy, Fonseca, Santos, Gama & Salema, 2015). Thus, the scenario "Help Somalia" was developed by two researchers in such a way that PSTs could demonstrate their knowledge and critical thinking skills during the argumentation process.

Four discussion questions were prepared for the scenario (Sadler, 2004). In the first question, the researchers aimed to reveal what positions the participants were taking, in the second question why they had taken these positions, in the third question the possibilities of counterarguments, and in the fourth question the ability to refute arguments. The content validity of the questions were consulted with two professors, one assistant professor, and one expert science educator working in the field of science education. Researchers examining the questions indicated that interview questions are appropriate. A pilot interview was conducted with four PSTs to determine if enough data could be collected with these questions during the argumentation process. As a result of the pilot study, the interview questions were considered appropriate and used for the main application.

d) Data Collection Process

209 PSTs were given the KT-GMOs, and then the collected data were sorted and transferred to an Excel file. The scores of the PSTs on the knowledge test and critical thinking scale were grouped from low to high level in terms of both knowledge and critical thinking skills. In accordance with the aim of the present study, out of 209 PSTs, the following were identified by means of the purposive sampling method: those with low-level content knowledge of GMOs and low-level critical thinking skills (5 PSTs); those with low-level content knowledge of GMOs and high-level critical thinking skills (5 PSTs); those with high-level content knowledge of GMOs and low-level critical thinking skills (5 PSTs); those a high-level of content knowledge of GMOs and a high level of critical thinking skills (5 PSTs).

This made a total of 20 PSTs. To examine the argumentation skills of these 20 PSTs, they were divided into five groups, with four people in each group. While the groups were being formed, instead of always putting participants who have similar levels of knowledge and critical thinking skills together, participants who have two different skill levels were also brought together in two groups. With this design, it was aimed to observe the argumentation skills of the PSTs at different levels more clearly. Figure 1 shows the PSTs participating in the argumentation sessions. In this way, it was tried to understand more clearly how argumentation skills vary as the skill levels differ.

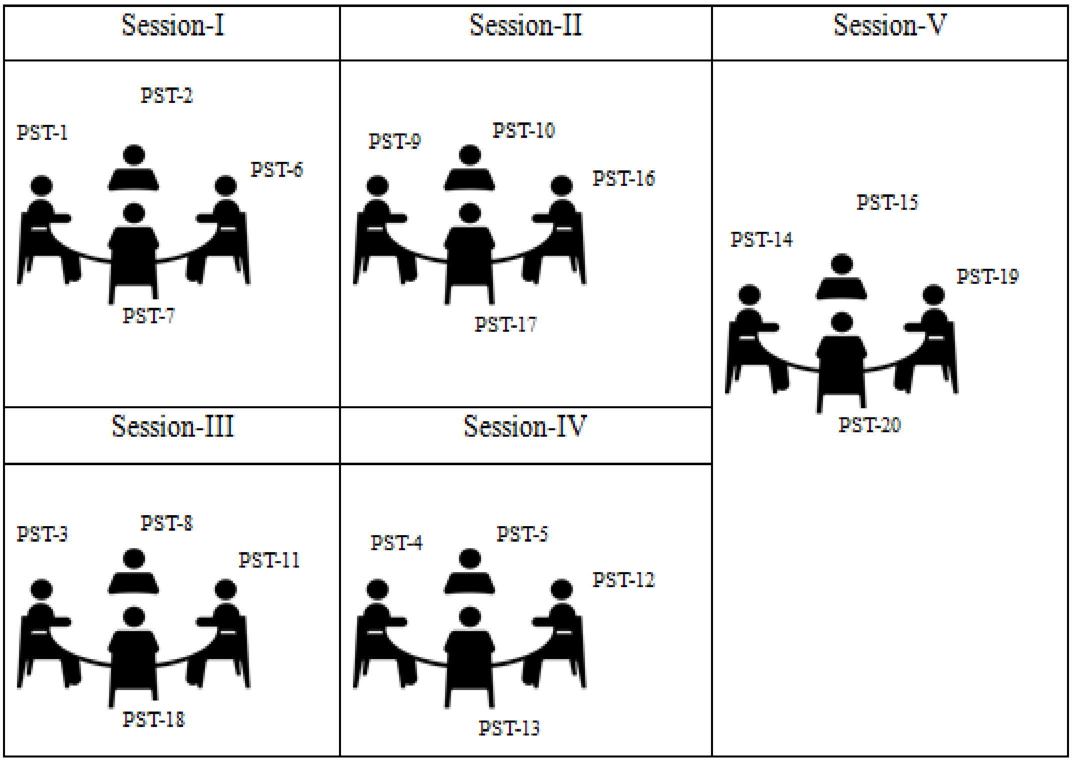


Figure 1. *PSTs seating order at the sessions*

In each session, one of the different levels of content knowledge or critical thinking skills was tested by placing two PSTs side by side. Argumentation sessions were arranged to be about 50 minutes for each of the five groups. In accordance with the nature of the SSI, each discussion group was initially played a video about GMOs. This video was designed to provide evidence that the participants could use during the debate. In putting this video together, we examined discussion programs, documentaries and news about GMOs. Then, we used the Movie Maker program to combine three programs which were most aligned to the nature of the study. It may be imagined that PSTs' knowledge of the subject would be influenced by the video display prior to the discussion. However, the subject of GMO is one that is frequently encountered in everyday life, both in visual and written media. Therefore, it is thought that the video did not actually increase the PSTs' knowledge.

Following the video presentation, each participant in the discussion group was given a text titled "Help Somalia". After the participants had read this, their opinions were sought by asking semi-structured questions aimed at identifying their argumentation skills. Subsequently, the participants presented the reasons why they had put forward their arguments. After the reasons they had presented, they were asked to say whether they were aware of any counterarguments. Finally, they were asked questions about how to refute these counter-claims. In addition, visual and auditory data were noted by the researcher. We took care to establish an environment that allowed free discussion by adhering to the nature of social constructivist theory (Schunk, 2012). The rules were set such as not interrupting whoever was speaking, using expressions related to the subject being discussed, and not making personal attacks on those advancing an opposing view. It was also wanted to offer encouragement to some of the PSTs who were not able to express themselves well.

e) Data Analysis and Interpretation

Five data analysis and interpretation stages were used as preparation, reduction of data to meaningful parts, naming of parts, combining codes under broad categories and themes, and comparison in data graphs, tables and charts (Creswell, 2012). The data were independently analyzed by two researchers and were combined after each stage. Each researcher's own codes, comments and notes were explained in the meeting of two researchers which held as video conferences. Similarities and differences were focused on. The themes formulated by the two researchers were not carried over into the next stage until they had reached 100% consistency. During the preparation phase, the interviews and discussion observations were put into written form. Each transcript obtained from the discussion was read at least three times. Notes were written in order to create links between raw data, possible categories and themes. Irrelevant expressions were deleted in the process of reducing the data to meaningful parts. It was determined that which of the answers given by the PSTs to the interview questions and the statements expressed at any time during the interview corresponded to the four factors namely skills in using warrants, counterarguments, rebuttals and evidence. At this stage, phrases and spoken expressions were separated, examined, compared and categorized. Then, in the process of combining ongoing codes into broad categories and themes, the codes for the PSTs, which had been dispersed throughout the course of the argumentation process, were combined under four themes. Finally, the PSTs' argumentation skills were evaluated in the four areas.

Warrant (W)

The participants were asked to justify their claims in the second discussion question. One point was given for each warrant. The scale (Table 2) that Sadler and Fowler (2006) developed in their study was used in the process of identifying the quality of warrants.

Table 2. *Warrant quality rubric*

Score	Description
0	No warrant
1	Warrant with no grounds
2	Warrant with simple grounds
3	Warrant with elaborated grounds
4	Warrant with elaborated grounds and a counter position

Counterargument (CA)

The third discussion question was asked to find out whether PSTs were aware of counterarguments. For each counterargument that the PSTs stated for this question, one point was given as the rubric studied by Erduran and Jimenez-Aleixandre (2007). They examined counterarguments in three levels in their study. Level 1 represents the lowest level, and the PSTs on this level were not able to make a claim, or their statements did not have the characteristics of counterargument. Level 2 represents the medium level. PSTs at this level identified a counterargument that was superficially justified. Level 3 represents the highest level. PSTs at this level identified, detailed, and justified counterarguments.

Rebuttal (R)

The participants' rebuttal skills were examined in the fourth discussion question. Since rebuttal skills are advanced skills, two points were given for each rebuttal (Lin and Mintzes, 2010). The scale developed by Erduran and Jimenez-Aleixandre (2007) was used to identify the quality of rebuttals made. The quality of rebuttal was assessed as follows: a) if the counterargument was rebutted with a superficial warrant, it was categorized as a low-level rebuttal; b) if it was rebutted with a strong warrant, it was categorized as medium-level rebuttal; c) if it was rebutted with a strong warrant and evidence, it was categorized as a high-level rebuttal.

Evidence (E)

Scientific data, past experiences and logical explanations suggested by PSTs were accepted as true and for each piece of evidence, one point was given. In order to examine the quality of the evidence, answers were sought to four questions developed from the studies of Erduran and Jimenez-Aleixandre (2007). These were: a) Does the statement present evidence? Is it [the evidence] realistic?; b) Does the data used as evidence support the warrant?; c) Does the data used as evidence support the rebuttal?; d) What is the source of the data used as evidence? The aim was to identify the quality of the evidence used by answering these questions.

Finally, how the argumentation skills differed as a result of the different levels of content knowledge and critical thinking skills among the PSTs was interpreted by comparing the groups.

f) Trustworthiness

Trustworthiness indicates the credibility of the results. In order to increase the reliability of this study (Creswell, 2012; Lincoln & Guba, 1985), data collection was carried out over five lengthy sessions. All the participants were students of the author, who also interviewed them. The author teaches in first and second-grade physics laboratories and third-grade science laboratories, and is also a class adviser concerned with the official and personal affairs of the participants in the final class. This created a confidence that the participants were able to express their feelings without hesitation. In addition, triangulation of the data is important for research. For this, different types of data sources were used such as questionnaires, face-to-face interviews and interview observations. The researchers planned and organized all phases of this work. In data analysis, in particular, the data were independently analyzed by two researchers, resulting in long discussions about incompatible themes. In this way, the results of the analysis were further clarified and the main reasons were questioned for the relationship between argumentation skills, content knowledge and critical thinking.

FINDINGS

Following the results of the Knowledge Test about GMOs (KT-GMOs) and the Watson Glaser Critical Thinking Appraisal (WG-CTA), argumentation sessions were conducted with 20 of the 209 PSTs. The 20 PSTs were divided into four groups of five individuals (see in Table-1). Comparisons were made between these groups’ argumentation skills. Sub-problems 1a., 1b., 1c. and 1d. were individually examined to compare these groups’ argumentation skills.

In this section, descriptive findings relating to the PSTs are first given and their argumentation skills are then treated qualitatively.

a) Descriptive Findings

The 20 PSTs separated into four different groups according to their level of KT-GMOs and CT skills participated in discussions. In this process, participants' argumentation skills were examined in terms of warrants, counterarguments, rebuttals, and evidence. The scores for the skills that the PSTs demonstrated in the argumentation process was shown in Table 3.

Table 3. *Argumentation skill score of PSTs*

Groups	Level	PSTs	Warrant	Counter-arguments	Rebuttal	Evidence	Total Score
A	CT (Low) KT-GMOs (Low)	PST-1	2	1	2	1	6
		PST-2	1	1	0	0	2
		PST-3	1	0	0	1	2
		PST-4	1	1	0	0	2
		PST-5	2	1	0	0	3
		Mean	1.4	0.8	0.4	0.4	3
B	CT (High) KT-GMOs (Low)	PST-6	4	3	8	5	20
		PST-7	2	2	2	2	8
		PST-8	2	1	2	1	6
		PST-9	2	2	2	1	7
		PST-10	3	1	0	0	4
		Mean	2.6	1.8	2.8	1.8	9
C	CT (Low) KT-GMOs (High)	PST-11	2	1	2	1	6
		PST-12	3	1	2	4	10
		PST-13	4	1	4	1	10
		PST-14	5	1	2	1	9
		PST-15	1	3	4	1	9
		Mean	3.0	1.4	2.8	1.6	8.8
D	CT (High) KT-GMOs (High)	PST-16	3	3	10	2	18
		PST-17	5	4	6	0	15
		PST-18	2	1	4	1	8
		PST-19	1	3	8	2	14
		PST-20	1	4	6	2	13
		Mean	2.4	3.0	6.8	1.4	13.6

When Table 3 is descriptively examined, the group with the lowest total score appears to be Group-A. On the other hand, Group-D is the group with the highest score. The comparison of argumentation skills between the groups was shown in Figure 2.

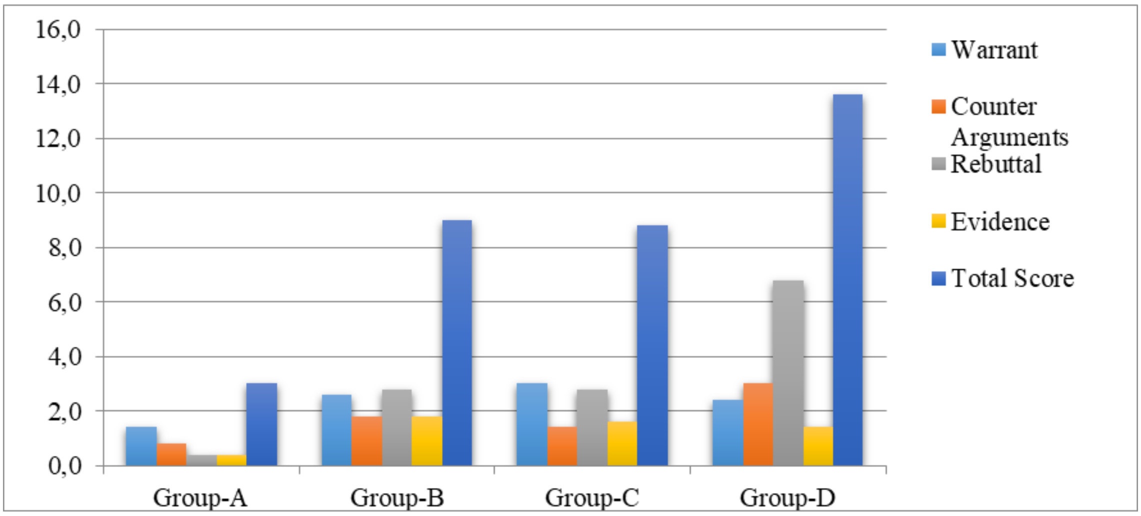


Figure 2. *Argumentation skills score of PSTs*

When Figure 2 is descriptively examined, it is seen that Group D's total argumentation skills, rebuttal and counter-argument skills are higher than the other groups in refuting and counter-claims.

b) Qualitative findings

Comparison of Group-A and Group-B's Argumentation Skills (1a. sub problem)

When argumentation skills of Group-A and Group-B are examined qualitatively, it is seen that there are some differences between skills in using warrants, rebuttals and evidence. Examples of the differences between the groups are given in Table 4.

Warrant skills: When the PSTs' statements were examined, it is clear that there are some differences between two groups. The PSTs in Group-B asserted stronger warrants than the other group in comparison of group warrants. Among the PSTs in Group-B, two PSTs asserted well-grounded, strong warrants, whereas three PSTs asserted warrants with simple grounds. This means that the PSTs' warrants in Group-B were at Level-2 and Level-3. Examining Group-A, it can be concluded that all PST's warrants are simple grounds or no grounds according to examination of Group-A. This means that the PSTs' warrants in Group-A were at Level-2.

Counterargument skills: When the statements of the PSTs are analyzed, some differences stand out between the two groups. Among the PSTs in Group-A, four PSTs made non-detailed, in other words, only superficially justified the counterarguments. And one PST did not use any statement eligible as a counterargument. The counterarguments put forward in the group were mostly at Level 2. It was ascertained that all of the PSTs in Group-B suggested superficially justified counterarguments. All of the counterarguments of the PSTs in this group were at Level 2.

Rebuttal skills: When the statements used for rebuttals by the PSTs are qualitatively analyzed, some differences stand out between these two groups. The rebuttal skills of the Group-B PSTs were more effective than the ones presented by Group-A. Two PSTs in Group-B rebutted the counterarguments by using warrants with simple grounds supported with evidence. One PST in this group had no rebuttal skills. So, Group-B PSTs rebutted partly in the low-high level. On the other hand, only one PST provided statements of rebuttal when the Group-A PSTs are analyzed. This PST rebutted the counterarguments by using warrants that were supported with evidence and simple grounds. The other PSTs in this group did not provide any statements of rebuttal.

Using evidence skills: When the statements used for rebuttals by the PSTs are qualitatively analyzed, some differences stand out between these two groups. In Group-B, four PSTs used data with evidence for the purpose of supporting their warrants or rebuttals. They generally used the statements of scientists in the video as a data source. In Group-A, only two PSTs presented data with evidence but others did not use any evidence. Two PSTs used the opinions of the scientists in the video as evidence in order to support their warrant or rebuttals.

Table 4. *Example statements of PSTs in Group-A and Group-B*

Argumentation skills	Example of PSTs statements
Warrant	PST-8: I would not send GMO products because the substances used in the production of GMO products will lead to resistance against medicine such as antibiotics in people who eat the food, and the medicine will not have any effect on the people even if we send it in the days immediately afterwards. PST-1: We cannot say that GM foods are harmful, and as we've seen in the studies, it's not so harmful. Africa is, as I said before, a barren place and its geographical structure has been destroyed. You can only grow plants which are resistant to those geographical conditions in such a destroyed geography. Now, you can pursue a policy like that. Thinking about it economically is also necessary.

Counterargument	PST-5: Someone who is against me might think that a natural diet is better for the health of the community. PST-9: Of course, the people are hungry there and it isn't known when the aid will arrive. Let's send those people natural food, but once this food has been used up, they won't know when the next aid will arrive.
Rebuttal	PST-8: Let's say you've sent GMO products. Assume that you don't have any money one year later and you've caused those people to get sick. What would you do in such a situation? You state that the people may live for another six months through GMO food aid. However, let's suppose that you have sent GMO products and after a year, you don't have any money and you've caused those people to get sick. This situation may cause worse results. That kind of problem may arise. PST-1: You say it's dangerous, but you need to provide evidence. In the video a professor said that more than 410 research studies had been conducted. So it's not like you claimed. No negative results were found in those studies. Has anyone said that they are affected by these animals or GMOs in the last 10 years?
Evidence	PST-6: When we consider the statements of the oncologist in the video, he said that: I can say that fertility has considerably decreased in animals, with increasing miscarriage in areas where excessive planting has been carried out, especially in the last two years. Studies that have considered this point of view have given the obvious result that GMOs are toxic. Therefore, there is evidence supporting their association with cancer. PST-1: You say it's dangerous, but you need to provide evidence. In the video a professor said that more than 410 research studies had been conducted. So, it's not like you claimed. No negative results were found in those studies. Has anyone said that they are affected by these animals or GMOs in the last 10 years?

Comparison of Group-A and Group-C's Argumentation Skills (1b. sub problem)

When the Group-A and Group-C's argumentation skills were qualitatively examined, it can be seen that there are some differences among warrant, rebuttal and the using evidence skills of the two groups. Examples of the differences among the groups are given in Table 5.

Warrant skills: When the PSTs in Group-C are analyzed, it is seen that all PSTs in this group, warrants with elaborated grounds, supported with scientific and logical information. PSTs in Group-C used Level-3 warrants. When Group-A is analyzed, it is found that all PSTs used warrants with no grounds or simple grounds. In this group, all PSTs used Level-2 warrants.

Rebuttal skills: When the PSTs' statements qualitatively examined for rebuttal in both groups, Group-C rebuttals are at a higher level than the Group-A. It is seen that the rebuttal statements of all the PSTs in Group-C manifest quality rebuttals. In this group, three PSTs made high-level rebuttals by using warrants. In Group-A, only PST-1 made a statement of rebut. He tried to use an evidence-based rebuttal, but his warrant was weak. In this group, the other PSTs were not able to make rebuttal statements.

Using evidence skills: When the PSTs' statements are qualitatively examined, some differences stand out between the two groups. All of the five PSTs in Group-C used statements with high quality evidence than Group A. In group B, PSTs used data, which they asserted to show evidence, to support their rebuttals. In comparison with the others in Group-A, PSTs were not able to use statements with high-quality evidence. In this group, one PST used evidence to support his rebuttal while rebutting counterarguments and one PST used evidence to make her warrant stronger. The difference between the data sources that both groups used for evidence is also noteworthy. While the PSTs in Group-A provided evidence, they used only expert opinions from the video. The PSTs in Group-C, however, used scientific articles and the knowledge they had obtained in university courses in addition to the expert opinions from the video.

Table 5. *Example statements of PSTs in Group-A and Group-C*

Argumentation skills	Example of PSTs statements
Warrant	PST-13: Even if it is said that it's not causing any trouble right now, I think it will create problems in terms of human health since the structure of the DNA has been changed and created by human beings in a laboratory environment. PST-2: My reason is that people would live more healthily.
Rebuttal	PST-14: You say we haven't seen any negative results so far. As you said, GMO doesn't affect human health immediately, it happens in a lengthy process. PST-1: You say it's dangerous, but you need to provide evidence. In the video a professor said that more than 410 research studies had been conducted. So it's not like you claimed. No negative results were found in those studies. Has anyone said that they are affected by these animals or GMOs in the last 10 years?
Evidence	PST-3: GM food may cause a lot of illnesses like thyroid cancer, as the expert in video mentions here. PST-11: According to an expert in the video, growing genetically modified corn in Mexico may affect related species there. However, if GM corn from Mexico is grown in Turkey, there won't be any issue since there isn't any related species to pollinate.

Comparison of Group-B and Group-D's Argumentation Skills (1c. sub poblem)

When the argumentation skills of Group-B and Group-D qualitatively compared, a number of differences were found in the skills regarding warrants, rebuttals and using evidence. Examples of the differences between the groups are given in Table 6. The sub-skills of that stand out as qualitatively different between the two groups are:

Warrant skills: Although Group-B displayed more warrant skills than Group-D, PSTs in Group-D put forward stronger warrants. In Group-D, all PSTs proposed elaborate warrants. Overall, the warrants of Group-D PSTs were at Level-3. Among the PSTs in Group-B, two PSTs asserted well-grounded, strong warrants but three PSTs asserted warrants with simple grounds. This means that the PSTs' warrants in Group-B were at Level-2 and Level-3.

Rebuttal skills: The rebuttal skills of Group-D were more effective than those of Group-B. In Group-B, two PSTs made high-level rebuttals through the use of strong warrants with evidence. Two PSTs made low-level rebuttals, refuting counterarguments with superficial warrants. Only one PST did not use rebuttal statements. In Group-D, four PSTs made high-level rebuttals using well-grounded warrants with evidence.

Using evidence skills: In Group-B, three PSTs used the opinions of the scientists in the video as evidence to back up their rebuttals. One PST used information from scientific journals as evidence to back up their warrants. One PST in the same group did not use any statements with evidence. On the other hand, four PSTs in Group-D used data as evidence to support their warrants or rebuttals. Their evidence sources were the video, their biology lecture notes and science conferences. Only one PST did not use any statement with evidence.

Table 6. *Example statements of PSTs in Group-B and Group-D*

Argumentation skills	Example of PSTs statements
Warrant	PST-20: We are talking about six-month and one year-long processes. You've sent natural goods for six months and fed them. So what? After six months, they'll start dying again, because after six months, people will starve to death. I want them to live longer than just to starve to death. PST-9: If we send GMO processed food instead of natural food, I think that the people there will get harmed through the dissolution of their DNA and gene sequences because we have specific gene sequences. When you insert a different substance, this changes the sequence and has a specific effect.
Rebuttal	PST-9: My friend! You are against the opinion of the professor, which is that "the soil will be destroyed" and you think that's ridiculous. According to the expert in the video, the soil where GMOs are planted isn't destroyed, but it loses productivity. PST-16: For instance, he was not able to provide any clear data and say that was the number. If he had mentioned that he could have changed my ideas, but no one can say that. What they say is: "Therefore, they have found clear connections between them and cancer." That is a very political answer. Kidney cancer is increasing…That is not solely related to GMOs. We consume trans fats....Leave aside the food we consume…The reason is not GMOs. It's not only GMOs that leave toxic substances in my body… Later on, they look for a scapegoat and it gets to be GMOs.
Evidence	PST-8: Even though I am not a mother right now, I am against children being fed with GMO products. In the end, when a woman is pregnant, the baby takes in what the mother consumes and GMO is transferred to it. Moreover, a study showed that GMO caused the stomach walls of mice to get thicker and for them to have problems in the digestive systems. PST-19: My dear friend! You said that we can make people live for six months longer by sending GMO products, but we don't know what results GMO food will produce. Who will answer to the people whose genetic systems have been disrupted as a result of harmful genes due to a problem in the DNA being transmitted to genital genes?

Comparison of Group-C and Group-D's Argumentation Skills (1d. sub problem)

When the argumentation skills of Group-C and Group-D qualitatively compared, a number of differences were found in their rebuttal skills. Examples of the differences between the groups are given in Table 7.

Rebuttal skills: When the statements of the PSTs are qualitatively analyzed, some differences stand out between these two groups. The rebuttal skills of Group-D were more effective than those of Group-C. Analyzing the groups, in Group-C three PSTs made high-level rebuttals through the use of strong warrants with evidence. On the other hand, one PST made a low-level rebuttal by rebutting counterarguments through a warrant with simple grounds. And another PST made medium-level rebuttals by rebutting counterarguments with well-grounded warrants. In Group-D, four PSTs made high-level rebuttals through the use of well-grounded warrants with evidence. In this group, only one PST made medium-level rebuttals by rebutting counter-arguments with well-grounded warrants.

Table 7. *Example statements of PSTs in Group-C and Group-D*

Argumentation skills	Example of PSTs statements
	PST-15: PST-20 has mentioned cancer, she said that GMO may be a possible cause of cancer, but it seems like she's asserting that cancer is a disease that is unlikely to occur. However, today there is no definitive treatment for cancer. Drugs are produced, but they can't directly prevent it because I think that the drugs are only produced in order for the drug companies to make a profit.
Rebuttal	PST-20: PST-19 says that if natural seeds are sown, we can obtain more fruits, but I know from my own life that when, for instance, we go to the highlands in summer, is there anything like local tomatoes? No! On one hand, you plant the seeds that you get from abroad, and on the other hand you plant the local seeds that you get from the farmers, but you can't grow any fruit. You don't produce anything from natural seeds. What does the farmer do as a result? He's not growing anything, and therefore doesn't plant natural seeds.

DISCUSSION and CONCLUSION

The results of the study indicated that the PSTs in Group-B used the warrant, counter-argument, rebuttal, and using evidence skills more effectively than the PSTs in Group-A. When the PSTs' warrant skills were examined, it was found that while three PSTs in Group-B gave detailed warrants and two used superficial warrants, all the PSTs in Group-A stated superficial warrants. When the PSTs' counterargument skills were examined, it was found that in Group-A, two PSTs did not use counterarguments and three of them used non-detailed and superficially justified counter-arguments. However, all of the PSTs in Group-B used superficially justified counter-arguments. Regarding rebuttal skills, four PSTs in Group-A did not make any statements of rebuttal. However, four PSTs in Group-B used weak rebuttal statements with superficial warrants or warrants with evidence. It was observed that a number of differences between two groups in terms of the PSTs skills in using evidence. In Group-A, three PSTs used evidence to support their rebuttals or warrants, but two PSTs did not use any evidence. On the other hand, four PSTs in Group-B used the data as evidence to support their rebuttals, warrants, or both. There may be various reasons for this result. When analyzing the videos of the argumentation process, it was observed that the PSTs in Group-B also expressed skills such as open-mindedness, focusing and understanding the missing parts of the counterarguments.

Because the PSTs in Group-B had high-level critical thinking skills, it was observed two essential behaviors in them. First, in observations made during the argumentation process, it was determined that preservice teachers are good listeners with high-level critical thinking skills. In the argumentation process, they paid attention to opposing ideas in a respectful manner and tried to understand these ideas before stating their own opinions. Similarly, when they noticed that the opposing group had contradictory ideas, they tried to rebut these ideas by attending to the contradictions. Second, critical thinkers were capable of understanding the differences between claims and facts and recognizing inconsistent judgments within counterarguments. These findings suggest that in a socio-scientific context, PSTs' argumentation skills, such as their capacities to use warrant, counterargument, rebuttal and evidence, can be improved by enhancing their critical thinking skills without taking into account their content knowledge. Critical thinkers are individuals with metacognitive skills, who are aware of their own ideas (Paul & Elder, 2001). This feature of critical thinking may have encouraged these PSTs to use more detailed reasoning to support their claims. According to Bandura (1986), there is a close relationship between critical thinking and self-regulation. Critical thinkers not only act according to the preferences of others, but also based on their own evaluations and standards (Schunk, 2012). These results suggest that focusing on critical thinking skills alone is sufficient to bring argumentation skills to a high level.

The comparison of Group-B and Group-D showed that having content knowledge is vital in order to improve argumentation skills. In terms of argumentation skills (warrant, rebuttal and using evidence), it was observed that Group-D was more effective than Group-B. The analysis of the PSTs' warrants suggested that three PSTs in Group-B gave detailed warrants and two gave superficial warrants. On the other hand, all PSTs in Group-D used detailed and well-grounded warrants. When the differences were analyzed between the two groups regarding the skill of rebuttal, it was observed that four PSTs in Group-B offered a weak rebuttal by using weak warrants or warrants with evidence. However, all of the PSTs in Group-D were able to use statements of rebuttal, and most of their stated rebuttals were advanced. When the evidence used by the two groups was examined, four PSTs in Group-B used data from the video as evidence to strengthen warrants and rebuttals. In Group-D, three PSTs used data from the video, lecture notes and conferences as evidence to strengthen their rebuttals. When the argumentation skills score table was analyzed, it was observed that the evidence skills score of D group was lower than the B group. It showed that the use of evidence of D group was lower than the other group. In fact, in terms of quality, PSTs in group D used their evidence for rebuttal, while some of PSTs in group B used their evidence for rebuttal and others used it for supporting their claims. Accordingly, it can be said that PSTs in group D use effective evidence than B group.

Even without knowledge of GMOs, critical thinkers in a debate may display cognitive skills such as focusing, finding missing parts, being open-minded, understanding counterarguments and having a strategy for discussion. However, these skills alone are not enough to disprove opposing views. Since the PSTs did not know which information was right or wrong, they could not efficiently use all the features of that information, despite being aware of some of these features. The PSTs who have high level of GMO knowledge and critical thinking skills challenged the accuracy of the evidence and information presented by the opposing group in more efficient way. Therefore, they were able to use efficient warrants, rebuttals, and evidence that were all of a higher quality. The PSTs in Group-D had studied GMO in the "Special Topics in Biology" course. However, the PSTs in Group-B had not taken this course. As stated earlier, their high-level of knowledge about GMOs might be due to the PSTs being motivated with regard to the topic and discussion, and their increased self-efficacy.

It was supposed that, there were important relationships among the PSTs' goals, attributions, abilities, motivational behaviors and social behaviors. When faced with obstacles and failures, people who harbor self-doubts about their capabilities make fewer efforts or quickly give up (Bandura, 1988). Conversely, those who have a strong belief in their capabilities exert greater effort when they fail to master a challenge, and this strong perseverance contributes to individuals' accomplishments in their performance. During the argumentation process, the PSTs with high-level content knowledge felt comfortable in contributing to this study and in constructing arguments around this SSI. On the other hand, the PSTs in the low-level GMOs knowledge group were not comfortable when presenting arguments. According to Schunk (2012), people's ways of dividing up the elements of language elements reflect their deep mental structures. Therefore, the PSTs with high-level knowledge had more advanced thoughts with regard to GMOs than the PSTs with low-level knowledge levels. Sandoval and Millwood (2005) stated that coordinating claims and evidence is not an easy cognitive skill. They highlighted the high level of content knowledge needed for students to have an adequate amount of information about the meaning of evidence, what can be used as evidence, and what kind of relationship there is between claim and evidence.

Researchers (Driver et al. 2000; Zohar & Nemet, 2002; Braund et al. 2013) who have investigated the use of critical thinking in the argumentation process have stated that the use of critical thinking skills enables students to critically question socially-accepted claims, strengthen their supporting arguments and their rebuttals with evidence, and consequently increases their eagerness to take personal responsibility in the argumentation process. Furthermore, critical thinking skills enable students to pay attention to an argument and to be eager to respond to other group members, and so contribute to their reasoning when integrating new evidence into their existing knowledge. Finally, they enable students to test and evaluate the claim or theories suggested during an argument.

IMPLICATIONS AND LIMITATIONS

The purpose of this holistic multidisciplinary design was to investigate the relations among the PSTs' argumentation skills, their critical thinking skills and their content knowledge with regard to GMOs. A number of data collection tools were used to understand the argumentation process and underlying sources of these relationships. The findings showed that PSTs with high-level content knowledge were highly motivated to participate in the argumentation process. In addition, PSTs with high-level critical thinking skills were capable of building strategies to refute the statements of the opposing group. However, it was not enough to explain the process of argumentation, which is a very complicated process, with these two factors alone.

As a result of analyzing observational recordings, it was noticed that the process of making an argument is a rather complicated mechanism involving cognitive mechanisms, the teacher's beliefs, language skills and social skills. Hence, efforts to develop PSTs' argumentation skills will not be sufficient if those developing a curriculum incorporate argumentation without understanding the nature of this complex mechanism. In other words, when using new approaches such as argumentation, it is not possible to structure the discussion of the SSI even during the undergraduate period. Therefore, it was recommended to examine the effects of the PSTs' cognitive skills, social skills, language skills and communication skills on their argumentation skills.

In the present study, a measurement tool was used which focused on five dimensions of critical thinking. These five dimensions were as follows: Deduction, awareness of assumptions, interpretation and evaluation of opposing views. In the literature, it was found that it was not yet clear what the limits of critical thinking are. By using other measurement tools designed to measure the PSTs' critical thinking skills, it was aimed to examine the differences in their argumentation skills in different sub-dimensions. There is a need for new studies to examine the relationship between the PSTs' argumentation skills and each sub-dimension.

It was found that low motivation and reluctance among PSTs constituted a strong obstacle to their participation in the argumentation process. Hence, opportunities should be created to keep their motivation high at every stage of the discussion, although these opportunities are limited in crowded argumentation groups and a small number of PSTs will tend to have an active role in the process. However, studies could be conducted in which argumentation environments are more regulated.

As with all scientific studies, this study involves certain limitations. First, as a holistic multiple-case study, it was conducted with a total of 20 PSTs, each consisting of five individuals. Second, the WG-CTA scale included only the dimensions that represented critical thinking. Because many researchers have used this data collection tool, only five dimensions were used in this study. Moreover, the item dimensions in the measurement tool were not included in the SSI.

In this study, the WG-CTA scale measured general critical thinking skills. However, the PSTs' critical thinking skills may depend on the subject discussed, and it was suggested to develop a new critical thinking scale for SSIs. Moreover, this study focused only on the issue of GMOs. Future studies could investigate how the relationship between the PSTs' argumentation skills and their critical thinking skills and content knowledge would change if they focused on other SSI, for instance nuclear energy, global warming and gene therapy.

Finally, it was concluded that the other factors besides critical thinking and content knowledge (communication skills, the nature of science, epistemological beliefs and culture) also influence argumentation skills. Researchers could examine the relationship between these factors and argumentation skills.

REFERENCES

Acar, Ö. (2016). Examination of science learning equity by argumentation instruction between students having different socio-economic status and attending different achievement level schools. *Journal of Turkish Science Education*, *13*(4), 262-280.

Albe, V., & Simonneaux, L. (2005). Epistemological thought and role-playing: Impact on pre-service teachers' opinions on mobile phone risks. In *Research and the Quality of Science Education* (pp. 181-191). Springer Netherlands.

Albe, V. (2008). When scientific knowledge, daily life experience, epistemological and social considerations intersect: Students' argumentation in group discussions on a socio-scientific issue. *Research in Science Education*, *38*(1), 67-90.

Aydeniz, M., & Ozdilek, Z. (2015). Assessing pre-service science teachers' understanding of scientific argumentation : What do they know about argumentation after four years of college science? *Science Education International*, *26*(2), 217–239.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs, NJ: Prentice Hall.

Bandura, A. (1988). Self-regulation of motivation and action through goal systems. In V. Hamilton, G. H. Bower, & N. H. Frijda (Eds.), *Cognitive perspectives on emotion and motivation*(pp. 37–61). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Bandura, A. (1997). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, *84*, 191–215.

Barrue, C., & Albe, V. (2013). Citizenship education and socioscientific issues: Implicit concept of citizenship in the curriculum, views of French middle school teachers. *Science & Education*, *22*(5), 1089-1114.

Braund, M., Scholtz, Z., Sadeck, M., & Koopman, R. (2013). First steps in teaching argumentation: A South African study. *International Journal of Educational Development*, *33*(2), 175-184.

Carvalho, C., Fiuza, E., Conboy, J., Fonseca, J., Santos, J., Gama, A. P., & Salema, M. H. (2015). Critical thinking, real life problems and feedback in the sciences classroom. *Journal of Turkish Science Education*, *12*(2), 21-31.

Creswell, J. W. (2012). *Qualitative inquiry and research design: Choosing among five approaches* (3rd Ed.). London: Sage Publications.

Çıkrıkçı, N. (1993). Watson-Glaser eleştirel akıl yürütme gücü ölçeğinin (Form YM) lise öğrencileri üzerindeki ön deneme uygulaması. *Ankara Üniversitesi Eğitim Bilimleri Fakültesi Dergisi*, 25(2), 559–569.

de Lima Tavares, M., Jiménez-Aleixandre, M. P., & Mortimer, E. F. (2010). Articulation of conceptual knowledge and argumentation practices by high school students in evolution problems. *Science & Education*, *19*(6-8), 573-598.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science education*, *84*(3), 287-312.

Erduran, S., & Jimenez-Alexandre, M. P. (Eds.). (2007). *Argumentation in science education: Recent developments and future directions*. New York, NY: Springer

Erika, F., & Prahani, B. K. (2017). Innovative chemistry learning model to improve argumentation skills and self-efficacy. ***Journal of Research & Method in Education***, *7*(1), 62-68.

Eskin, H., & Ogan-Bekiroglu, F. (2013). Argumentation as a strategy for conceptual learning of dynamics. *Research in Science Education*, *43*(5), 1939-1956.

Facione, P. A. (1991). *Critical thinking: What it is and why it counts*. Millbrae, CA: California Academic Press.

Foong, C. C., & Daniel, E. G. (2013). Students’ argumentation skills across two socio-scientific issues in a confucian classroom: Is transfer possible? *International Journal of Science Education*, *35*(14), 2331-2355.

Freeley, A. J., & Steinberg, D. L. (2013). *Argumentation and debate, critical thinking for reasoned decision making*. Wadsworth Cengage Learning.

Gaskell, G., Allansdottir, A., Allum, N., Corchero, C., Fischler, C., Hampel, J., Jackson, J., Kronberger, N., Mejlgaard, N., Gemma, R., Schreiner, C., Torgerseni H., & Wagner, W. (2006). Europeans and biotechnology in 2005: patterns and trends. *Final report on Eurobarometer*, *64*(3).

Jiménez-Aleixandre, M. P., Rodriguez, A. B., & Duschl, R. A. (2000). "Doing the lesson" or "doing science": Argument in high school genetics. *Science Education*, *84*(6), 757-792.

Jiménez-Aleixandre, M. P., & Puig, B. (2012). Argumentation, evidence evaluation and critical thinking. In *Second international handbook of science education* (pp. 1001-1015). Springer Netherlands.

Khishfe, R., Alshaya, F. S., Boujaoude, S., Mansour, N., & Alrudiyan, K. I. (2017). Students’ understandings of nature of science and their arguments in the context of four socio-scientific issues. *International Journal of Science Education*, *39*(3), 299-334.

Kilinc, A., Demiral, U., & Kartal, T. (2017). Resistance to dialogic discourse in SSI teaching: The effects of an argumentation-based workshop, teaching practicum, and induction on a preservice science teacher. *Journal of Research in Science Teaching*, *54*(6), 764-789.

Kilinc, A., Kelly, T., Eroglu, B., Demiral, U., Kartal, T., Sonmez, A., & Demirbag, M. (2017). Stickers to facts, imposers, democracy advocators, and committed impartialists: Preservice science teachers’ beliefs about teacher’s roles in socioscientific discourses. *International Journal of Science and Mathematics Education*, *15*(2), 195-213.

Kuhn, D. (1991). *The skills of argument*. Cambridge University Press.

Kuhn, D. (1999). A developmental model of critical thinking. *Educational researcher*, *28*(2), 16-46.

Lin, S. S., & Mintzes, J. J. (2010). Learning argumentation skills through instruction in socioscientific issues: The effect of ability level. *International Journal of Science and Mathematics Education*, *8*(6), 993-1017.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Beverly Hills, CA: Sage Publications.

Liu, S., & Roehrig, G. (2017). Exploring science teachers’ argumentation and personal epistemology about global climate change. *Research in Science Education*, 1-17.

Mason, L., & Scirica, F. (2006). Prediction of students' argumentation skills about controversial topics by epistemological understanding. *Learning and Instruction*, *16*(5), 492-509.

Ministry of National Education (MNE) (2013). Science education curricula (Grades 3–8). Retrieved from http://ttkb.meb.gov.tr/. Accessed on December 24, 2015.

Moore, F. M. (2008). The role of the elementary science teacher and linguistic diversity. *Journal of Elementary Science Education*, *20*(3), 49-61.

Ogan-Bekiroglu, F., & Eskin, H. (2012). Examination of the relationship between engagement in scientific argumentation and conceptual knowledge. *International Journal of Science and Mathematics Education*, *10*(6), 1415-1443.

Öğreten, B., & Uluçınar-Sağır, Ş. (2014). Argümantasyona dayalı fen öğretiminin etkililiğinin incelenmesi. *Türk Fen Eğitimi Dergisi*, *11*(1), 75-100.

Paul, R., & Elder, L. (2001). *The miniature guide to critical thinking: Concepts & tools*. Foundation Critical Thinking.

Sadler, T. D. (2003). *Informal reasoning regarding SSI: The influence of morality and content knowledge.* (Unpublished Doctoral Dissertation, University of South Florida, Florida.)

Sadler, T. D., Chambers, F. W., & Zeidler, D. L. (2004). Student conceptualizations of the nature of science in response to a socioscientific issue. *International Journal of Science Education*, *26*(4), 387-409.

Sadler, T. D., & Donnelly, L. A. (2006). Socioscientific argumentation: The effects of content knowledge and morality. *International Journal of Science Education*, *28*(12), 1463-1488.

Sadler, T. D., & Fowler, S. R. (2006). A threshold model of content knowledge transfer for socioscientific argumentation. *Science Education*, *90*(6), 986-1004.

Sadler, T. D., & Zeidler, D. L. (2005a). Patterns of informal reasoning in the context of socioscientific decision making. *Journal of research in science teaching*, *42*(1), 112-138.

Sadler, T. D., & Zeidler, D. L. (2005b). The significance of content knowledge for informal reasoning regarding socioscientific issues: Applying genetics knowledge to genetic engineering issues. *Science Education*, *89*(1), 71-93.

Sadler T. D., & Zeidler, D. L. (2009). Scientific literacy, PISA, and socioscientific discourse: Assessment for progressive aims of science education. *Journal of Research in Science Teaching*, 46, 909–921.

Sandoval, W. A., & Millwood, K. A. (2005). The quality of students' use of evidence in written scientific explanations. *Cognition and instruction*, *23*(1), 23-55.

Saracaloglu, A., S., Aktamis, H., & Delioglu, Y. (2011). The impact of the development of prospective teachers' critical thinking skills on scientific argumentation training and on their ability to construct an argument. *Journal of Baltic Science Education*, 10(4), 4243–260. ISSN 1648–3898.

Schunk, D. H. (2012). *Learning theories: An educational perspective* (6th ed.). Upper Saddle River, NJ: Pearson Prentice Hall.

Schweizer, D. M., & Kelly, G. J. (2005). An investigation of student engagement in a global warming debate. *Journal of Geoscience Education*, *53*(1), 75.

Sivan, E. (1986). Motivation in social constructivist theory. *Educational Psychologist, 21*, 209–233.

Sjöberg, L. (2004). Gene technology in the eyes of the public and experts. Moral opinions, attitudes and risk perceptions. (SSE/EFI Working Paper Series in Business Administration 2004: 7), Stockholm: Stockholm School of Economics.

Snyder, C. R., & Lopez, S. J. (2009). *Oxford handbook of positive psychology*. Oxford University Press, USA.

Sönmez, A., & Kılınç, A. (2012). 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.

Topcu, M. S., Sadler, T. D., & Yilmaz-Tuzun, O. (2010). Preservice science teachers' informal reasoning about socioscientific issues: The influence of issue context. *International Journal of Science Education*, *32*(18), 2475-2495.

Toulmin, S. (1958). *The uses of argument*. Cambridge: Cambridge University Press. 259.

Trend, R. (2009). Commentary: Fostering Students' Argumentation Skills In Geoscience Education. *Journal Of Geoscience Education*, *57*(4), 224-232.

Venville, G. J., & Dawson, V. M. (2010). The Impact Of A Classroom Intervention On Grade 10 Students' Argumentation Skills, Informal Reasoning, And Conceptual Understanding Of Science. *Journal Of Research In Science Teaching*, *47*(8), 952-977.

Von Aufschnaiter, C., Erduran, S., Osborne, J., & Simon, S. (2008). Arguing to learn and learning to argue: Case studies of how students' argumentation relates to their scientific knowledge. *Journal of Research in Science Teaching*, *45*(1), 101-131.

Voss, J. F., & Van Dyke, J. A. (2001). Argumentation in psychology: Background comments. *Discourse Processes*, *32*(2-3), 89-111.

Vygotsky, L. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Walker, K. A., & Zeidler, D. L. (2007). Promoting discourse about socioscientific issues through scaffolded inquiry. *International Journal of Science Education*, *29*(11), 1387-1410.

Yin, R. K. (2013). Case study research: Design and methods (applied social research methods) (5th Ed.). London, UK: Sage Publications, Inc.

Zeidler, D. L., & Nichols, B. H. (2009). Socioscientific issues: Theory and practice. *Journal of Elementary Science Education*, *21*(2), 49-58.

Zohar, A., & Nemet, F. (2002). Fostering students' knowledge and argumentation skills through dilemmas in human genetics. *Journal of Research in Science Teaching*, *39*(1), 35-62.

Appendix A: Scenario: Help to Somalia

Somalia is experiencing the driest period of recent years. Because of African countries' unconsciously water-sharing, there were thirst in some areas, in parallel with drying of agricultural products and, finally, the famine. People are trying to survive in internment camps with aid that will come from other countries. The United Nations (UN) is planning to provide food and medicines to these people who suffer from hunger in Somalia under the World Food Program (WFP), with money collected from many countries. Turkey is at the head of the countries participating in this aid campaign. You are the person responsible for the charity campaign. You will make food aid to Somalia with the money to be collected. Approximately 12.000.000 TL (approximately 3.000.000 $) cash was collected from Turkey. You can buy genetically modified food that will be enough for 1 year to the people who need food with this money in your hand, or you can buy natural food for up to 6 months with this money. There is a chance that new money will come from Turkey in the future, but it is not clear when. If you distribute food with GMOs, you will face up to potential risks, or if you distribute normal food, people in the camp will live in hunger for a while again.

Appendix B: Interview Questions

1. As a member of Somali Aid Commission, would you like to send GMO or natural food to Somali? What would you like to do in such a case? (*Taking position skills against a state were evaluated*)
2. What are your reasons to choose the position you take on help? (*Reasoning positions skills are evaluated*)
3. If someone disagrees with the view that you have stated in the first and second questions, then he/she is against some of your views and isn't convinced with some of your reasons. What could be the opposite opinions? (*The skills in creating counter-arguments of the participants are evaluated*)
4. How do you rebut someone who is against your views and how would you convince him? (*Producing supportive arguments to refute claims. The skills of the participants are evaluated*)