

Effectiveness of Concept Cartoons on 7th Grade Students' Understanding of “the Structure and Properties of Matter”

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ABSTRACT

The aim of this study is to determine the effect of concept cartoons on 7th grade students' acquiring the concepts in “The Structure and Properties of Matter” chapter. To reach this aim concept cartoons involving students' preconceptions and alternative conceptions about the concepts in the unit were developed. The data of the research was collected via the Structure and Properties of Matter's Concept Test (SPMCT) and semi-structured interviews. The sample of the research consisted of 49 grade 7 students in total, 24 students in experimental group and 25 students in control group. SPMCT prepared by considering the alternative conceptions obtained via the outcome of literature analysis was applied as a pre-test. And then, the unit of “the structure and properties of matter” with prepared concept cartoons was studied. At the end of the study, SPMCT was applied to the students as a post-test. At the end of the research, it was ascertained that students had varied alternative conceptions about studied concept, some of them learned the concepts of the structure and properties of matter at a level of knowledge, but were inadequate in applying them. In addition, the students chosen from the experimental group were interviewed with the intent of promoting the test results. As a result of analyzing the test and interview, it was ascertained that the application decreased the alternative conceptions on the structure and properties of the matter existing in students, did not reveal new alternative conceptions and got the students comprehend the subjects better.

Keywords: Concept cartoon, the structure and properties of matter, alternative conception

INTRODUCTION

The abstract nature of science subjects may result with different alternative conceptions while constructing these subjects in students' mind. Students starting the science education at earlier ages are expected to be learning the abstract concepts in science, which are even difficult to be conceptualized by adults. Therefore, this higher expectation makes the science concepts relatively difficult for teachers to teach. (Amir & Tamir, 1994). Additionally, students describe science classes difficult due to more intellectual activity requirement (Çepni, Akdeniz & Keser, 2000). Chemistry included in science curriculum with a number of



basic concepts is one of the most important fields of science. Research studies investigating the understanding, comprehension and conceptions show that students at all levels struggle with chemistry concepts and cannot be successful in desired level. While students learn several alternative conceptions related to fundamental chemistry concepts, they face with several cognitive conflicts when dealing with these concepts and find them difficult to learn in chemistry (Kirkwood & Symington, 1996; Lorenzo, 2005; Özmen, 2007; Taber, 2000).

One of the basic and abstract subjects of chemistry is “*Structure and Properties of Matter*”. Teaching microscopic nature of matter to students whose intellectual levels of development are not at the expected levels causes additional difficulty for students to clearly understand the relevant concepts. As a matter of fact that various alternative conceptions are observed about the subject when the studies in literature over the structure of matter are analyzed (Bektaş, 2003; Çakır, 2005; Griffiths & Preston, 1992; Harrison & Treagust, 1996; Nakhleh & Samarapungavan, 1999; Özmen, 2011a; Özmen, 2013; Tsai, 2001). Structure and properties of matter include fundamental concepts and correctly understanding these concepts affects the learning of other advanced level concepts (Özmen, Ayas & Coştu, 2002). In order to address problems in the learning and understanding fundamental concepts in chemistry, new and alternative teaching methods and materials are needed to be developed, which could enable students to understand these concepts easily and correctly.

Changing alternative conceptions is as important as teaching the concepts to the students correctly. Putting the conceptual change into practice requires students to realize that their prior knowledge was incorrect at first and then believe that the given knowledge is plausible and accurate (Chi & Roscoe, 2002; Ebenezer, Chacko, Kaya, Koya & Ebenezer, 2010; Piquette & Heikkinen, 2005; Posner, Strike, Hewson & Gertzog, 1982). And also, teachers should provide some opportunities for the students to make real conceptual change through various activities (Gooding & Metz, 2011). Literature reported that conceptual change strategies play a supportive role in promoting students’ core understanding (Howe, Devine & Taylor Tavares, 2013).

It is seen in the literature that there are many teaching methods, techniques and materials being used to develop students’ understanding and dispel the alternative conceptions (Chambers & Andre, 1997; Coll & Treagust, 2011; Guzzetti, Williams, Skeels & Wu, 1997; Huddle, White & Rogers, 2000; Keogh & Naylor, 1999; Özmen, Demircioğlu & Coll, 2009). In these studies it is stated that teaching methods and materials that activating the students have a positive effect on learning. Even though there are some studies in the literature investigating the effectiveness of different teaching materials on teaching the structure and the properties of matter (Akgün & Aydın, 2009; Balım, İnel & Evrekli, 2008; Chiu & Lin, 2005; Çepni, Akdeniz & Keser, 2000; İnceç, 2008; Özmen, 2011b), it is known that different materials being used in these studies are also mostly insufficient in concept teaching and correcting alternative conceptions. That most of the materials cannot meet the expectations sufficiently is one of the most important reasons for this. For example, it is stated that analogies could create new alternative conceptions (Huddle, White & Rogers, 2000; Orgill & Bodner, 2004; Thiele & Treagust, 1994), conceptual change texts could be boring and could create reading problems (Dole, 2000), and preparing worksheets is difficult and they could also be boring (Türk & Çalık, 2008). Therefore, along with the educational quality of the materials used in teaching process, it is also important that they should entertain the students during the implementation process. When considered for the primary education, we can talk about the attractiveness of the humorous approach in communicating the children. In this sense, cartoons are accepted to be an effective communication tools.

Concept cartoons were firstly introduced by Stuart Naylor and Brenda Keogh in 1991 (Karpudewan, MdZain & Chandrasegaran, 2017). They used them as a strategy to determine students’ ideas, to challenge their nonscientific beliefs and to provide insights into how these

ideas are developed (Keogh & Naylor, 1999). Concept cartoons provide students with a constructivist learning environment to participate in classroom discussions enjoyably (Ekici, Ekici & Aydın, 2007) and to express their ideas freely, especially in science and technology courses (Saka, Akdeniz, Bayrak & Asilsoy, 2006).

Concept cartoons were presented the students with science concepts (Karpudewan, MdZain & Chandrasegaran, 2017) and include a visual representation of a few characters in settings familiar to students along with the use of written language in speech bubbles (Keogh & Naylor, 1999; Sexton, 2010). In these cartoons, students read the dialogues and decide which character's views they agree with. In such a process, students have the opportunity to compare own ideas with ones found in cartoons, to listen the other students' views about the concept (Naylor & Keogh, 2013; Karpudewan, MdZain & Chandrasegaran, 2017) and to investigate and reinterpret the ideas in the cartoons (Kabapınar, 2005). Such an application gives students opportunity to dispel their alternative conceptions and construct the correct science concepts.

It is possible to communicate in an easy but not a complicated way via cartoons. In addition, cartoons have a feature of being remarkable, amazing and catchy (Dabel, 2008; Keogh & Naylor, 1999; Stephenson & Warwick, 2002). Cartoons have great importance in teaching and learning in terms of being not only humorous but also their psychological effects (Uğürel & Morali, 2006). Keogh and Naylor (1999) suggest using the concept cartoons as an original, encouraging, alternative and effective method providing a conceptual development in teaching and learning process.

Concept cartoons are often used by researchers as teaching and learning materials (Atasoy, Tekbıyık & Gülay, 2013; Chin & Teou, 2009; Dündar & Şentürk, 2012; İngeç, 2008; Kabapınar, 2005; Keogh & Naylor, 1999; Keogh, Naylor, Boo & Rosemary, 2002; Sexton, 2010; Taşlıdere, 2013). These studies report that concept cartoons have several benefits while using the educational purposes. For example, concept cartoons are effective in diagnosing and dispelling the alternative conceptions in science (Chin & Teou, 2009; Kabapınar, 2005; Keogh & Naylor, 1999). In addition, concept cartons are used for various purposes such as assessment tools (Chin & Teou, 2009; İngeç, 2008; Keogh et al., 2002), developing reading skills (Demetrulias, 1982), promoting investigations, motivation and involvement (Dündar & Şentürk, 2012; Kabapınar, 2005; Keogh & Naylor, 1996), solving problems (Jones, 1987), restructuring of ideas (Keogh & Naylor, 1996), promoting positive attitudes to science teaching and learning (Keogh et al., 2002), minimizing classroom management problems (Keogh & Naylor, 1999). Naylor and Keogh (2012) summarize some another benefits as developing language skills, engaging students in higher order thinking skills, creating interactive learning environments, auditing subject knowledge of student teachers, and effective stimuli for argumentation. And also, literature reports that concept cartoons are generally suitable for all ages of students (Karpudewan, MdZain & Chandrasegaran, 2017; Keogh & Naylor, 1999).

In the literature there are numerous studies stating that concept cartoons have a positive effect on learning and alternative conceptions (Kabapınar, 2005; Keogh & Naylor, 1999; Morris, Merritt, Fairclough, Birrell & Howitt, 2007; Stephenson & Warwick, 2002). Based on this data, we wondered in the present study that if the using of concept cartoons are effective way in teaching of the structure and the properties of matter. For this aim, a teaching material supported by concept cartoons was developed and its effect on learning was tried to be identified. In accordance with this aim, we tried to seek an answer for those two basic questions below:

1. Does the education supported by the concept cartoons have a statistically meaningful effect on learning?

2. To what degree could the concept cartoons have an effect on correcting the alternative conceptions?

METHODS

a) Research Method

A quasi-experimental design was used in the study. This method includes at least an experimental and a control group but the groups are not determined randomly. The points of each group from pre-test to post-test are compared and observed if there is a meaningful difference between the groups (Christensen, 2004).

b) Sample of the Study

It was used two different groups in this study. The first group is the one with 96 grade 7 students and also is the group on which the pilot study of the achievement test which is developed during the study was done. And the second group is composed of the students on whom the main study is conducted. The group is composed of two grade 7 classes consisting of 24 experimental and 25 control group's students attending to a primary school in Erdemli at Mersin.

c) Data Collection Tools

In this study the data were collected through The Structure and Properties of the Matter Concept Test (SPMCT) and semi-structured interviews. SPMCT consists of 19 two tier multiple-choice questions. The first tier of the test includes 2 or 3 answer choices and tests the students' knowledge as a multiple-choice format. And the second tier consists of 4 answer-choices asking students to justify their answers in the first phase. The second tier of the test involves multiple-choice options including students alternative conceptions determined from the findings obtained from the literature review. A literature survey has been done to prepare the test questions. All of the questions in the test were derived from the relevant literature (Çakmak, 2009; Çalık & Ayas, 2003; Ünal, 2007) and the 16th, 17th, 18th and the 19th questions were turned into two tier multiple-choice questions by the researchers. With the aim of checking the validity of SPCMT, the test was analyzed by three science teachers and an academic member who is an expert in chemistry education and corrections were made based on their view and suggestions. The reliability of the test was calculated with the SPSS 15.0 package software, Cronbach-Alpha method was used on the ground that the test consists of multiple grading questions and the reliability co-efficient of the test was found as $r = 0.76$. Two of the questions in the test are given as examples below.

Question 2. What do you think the structure of matter is like?

I-Continuous II- Particulate (*)

Which of the statements below could be the reason for your answer?

- A. Because the matter is seen continuous when observed with naked-eyes
- B. Because it is made up of little particles that are too small to be seen with naked-eyes (*)
- C. Because the matter is seen as continuous when looked at through a microscope
- D. Because the particles in matter are seen as continuous

Question 6. The gold is yellow. According to this, if we were able to separate an atom from a piece of golden wire by cracking it, would it be yellow too?

I- Yes II- No III- Atoms are colorless (*)

Which of the statements below could be the reason for your answer?

- A. Because the atom of the matter would be the same color as the matter.
 - B. Because it is the atom that colors the matter.
 - C. Because the colorfulness of the matter depends on the matters' characteristics of absorb and reflect the light (*)
 - D. Because the atom would lose its color because of the fraction
-

*: true answer

A semi-structured interview consisting of 13 questions was also conducted for determining the students' conceptual understanding. Eleven of the questions used in interview were taken from the related literature (Çakmak, 2009; Çalık & Ayas, 2003; Ünal 2007) and being turned into interview questions. The 10th and the 13th questions were developed by the researchers. The interviews were carried out with 9 students from the experimental group that the main study is conducted on. Three successful students (S2, S7, and S16), three mid-level students (S4, S13 and S24) and three unsuccessful students (S11, S20 and S21) were voluntarily chosen based on the concept test scores. The interviews were conducted by the first author of the study in the school's computer laboratory after applying the post-test. Each interview lasted 30 minutes and was type recorded. The interviews were analyzed by the three science teachers and an academic member who is an expert in chemistry education and essential changes in the test were done in accordance with their view and suggestions before implementing the interviews. The percentage of matches between experts was 89%. Subjects without a consensus were reassessed and finalized.

d) Developing the Concept Cartoons Used in the Study

Teacher's and the student's book were analyzed considering the learning outcomes in the unit before developing the concept cartoons. After that, the alternative conceptions regarding the subject were identified via the literature analysis. Concept cartoons were designed in accordance with the learning outcomes and the identified alternative conceptions. In making up the stories of the cartoons, we made use of the 7th grade teacher's guidebook of science, of the literature (URL1; URL2; Çakır, 2005; Çakmak, 2009) and of the views of the science teachers. On the phase of making up the stories of the cartoons, the views of the science teachers were considered and the concepts that they have difficulty in teaching were focused on. Concept cartoons consist of 6 series in which there are 20 frames in total. In preparing the 1st cartoon series, we were inspired by the metaphors in science teacher's guidebook and while teaching the abstract concepts such as atom, element and compound, onion cartoons were used to embody the abstractness of the concepts. In designing the 2nd cartoon series, we were inspired by the cartoons in the worksheets which were used in the study conducted by Çakmak (2009). In designing the 3rd cartoon series, we were inspired by the drawings and the pictures in the science teacher's guidebook. In preparing the 4th and the 5th series of cartoons, we were inspired by the animations on the net, demonstrating the atomic bonds. Concept cartoons which also included the alternative conceptions were developed to ensure the effective learning of the covalent bond and the ionic bond (URL1; URL2). Some of the cartoons developed by the researchers are given as an example below:

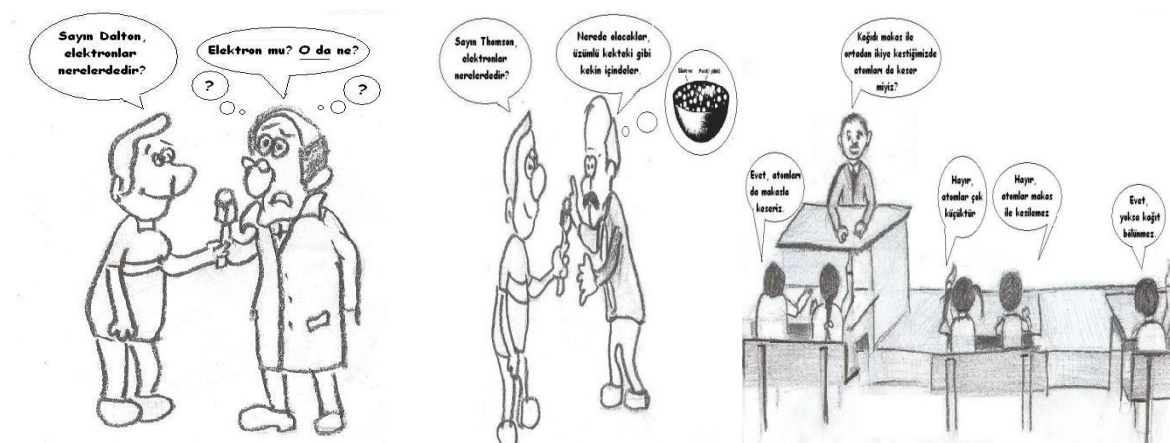


Figure 1. Samples of concept cartoons

e) Implementation Process

Both of the groups in the study were taught by the same science teacher. The teacher conducted text book and the teacher's guidebook-based instruction in the control group while he taught the same unit concept cartoon-based applications in experimental group. SPMCT was applied to both groups as pre-test before starting the implementation and as post-test a week after finishing the teaching of the unit. The application was completed by interviewing the 9 students after implementing the post-test. The teacher was informed before the main application about how to use the concept cartoons while teaching. What the aim to use of the concept cartoons is, what it is for, how it will affect the teaching and how to use it were explained to the teacher in detail. And then, the views and suggestions of the other science teachers were also taken by discussing with them related how to use the concept cartoons. As a result of these discussions, it was decided that it would be better to use the concept cartoons for discussions on the alternative ideas and for revealing the students' ideas on the subject. Finally, questions to assess the teaching at the end of the lesson were developed and it was decided to make the assessment through the concept cartoons. The teaching process in the control and the experimental groups is summarized on Appendix 1.

f) Data Analysis

SPMCT was applied to both groups at the beginning and at the end of the unit. In analysis, it was tried to be identified whether the students' answer were true at the first tier of the questions, and whether the reasons for the answers given at the first tier were true at the second tier. The points on table 1 were regarded in assessing the questions.

Table 1. *Points of Concept Test Questions*

The First Tier		The Second Tier		Total Score
Options	Points	Options	Points	
Correct Choice	3	Correct Reason	4	7
Wrong Choice	1	Correct Reason	4	5
Correct Choice	3	Wrong Reason	2	5
Not Answer	0	Correct Reason	4	4
Correct Choice	3	Not Answer	0	3
Wrong Choice	1	Wrong Reason	2	3
Not Answer	0	Wrong Reason	2	2
Wrong Choice	1	Not Answer	0	1
Not Answer	0	Not Answer	0	0

Even if it is wrong, the students' idea is always valuable, because the student has an idea about the concept. Therefore it is considered appropriate to give more points to the wrong answer than the question that is not answered. According to the table, the total score that a student could get is 113 when all the answers are correct. After that, the achievements of the experimental and control group students were compared to the independent t-test. Data obtained from the interviews were classified as "alternative conception", "partial understanding" and "correct understanding". In this classification, the scientifically correct explanations were accepted as correct understanding, the scientifically correct but deficient explanations as partial understanding and scientifically incorrect ones as alternative conception. These kinds of classifications are used in the literature (Abraham, Grzybowski, Renner & Marek, 1992; Çakmak, 2009).

FINDINGS

a) Results Obtained from the Test

SPCMT was applied to both groups as pre-test before the application and as post-test after the application in the study. It was observed with the independent t-test if there were any statistically significant difference between the groups. The results are presented below:

Table 2. *Statistical Results of Pre-test and Post-test between the Groups*

Application	Group	N	\bar{X}	ss	Sd	t	p
Pre-test	Experimental	24	39.96	4.1	47	.21	.83*
	Control	25	40.20	3.2			
Post-test	Experimental	24	120.08	3.53	47	7.38	.00**
	Control	25	109.64	6.54			

* $p > .05$; ** $p < .01$

As is seen in table 2, before the application it was determined that there was not a statistically significant difference between the experimental and the control group ($p > .05$). However, it was observed that there was a statistically significant difference between the success of the groups after the comparison of the post-test results ($p > .01$). As seen in the table, there is a remarkable increase in both groups but the increase in the experimental group is much more than the control group.

In addition to the statistical analysis, both groups students' alternative conceptions were determined based on the analysis of the pre-test and post-test implementation of the SPMCT. According to the results of SPCMT, the percentage of the alternative conceptions of the students in both groups is demonstrated on table 3. As seen in the table, thirty alternative conceptions were identified in total under the ten topics in the pre-test in the study, and it is observed that the rates of the alternative conceptions in both groups are close to each other. And according to the assessments regarding post-test results, it was determined that there was a decrease in the rate of alternative conceptions of both groups however, the rate of the experimental group's alternative conceptions was determined to be far less than the control group's ones. While thirteen of the alternative conceptions were completely corrected in the control group, the number of the corrected alternative conceptions in the experimental group is nineteen. Some of the alternative conceptions were still present in both groups in post-test. While the alternative conceptions in the experimental group according to the post-test range from 4.2% to 8.2%, this percentage in the control group is between 4% and 16%.

Table 3. *Percentage of the Alternative Conceptions in Pre-Test and Post-Test*

Classification	Alternative conception	Control Group		Experimental Group	
		Pre-test (%)	Post-test (%)	Pre-test (%)	Post-test (%)
The atom is visible	Because the microscope enlarges the small particles	52	12	45.8	4.2
	Because the technology we have allows it	8	8	12	-
	Because there are the shapes of atoms in books	12	-	20.8	-
The atomic models are real	Because the scientists see atoms and draw their models	52	8	50	4.2
	Because the scientists explore the atomic models doing experimental researches	20	12	25	4.2
	Because the models are drawn with the help of microscope	16	-	12.5	-
If a matter is crushed, its atoms are also crushed	Because with the process of crashing atoms would get thinner and longer	20	-	12.5	-
	Because after the process of crashing, the volume of the atoms would decrease and their shapes would change	32	-	21.9	-
	Because after the process of crashing some of the atoms would be crashed and form different atoms	24	8	37.5	4.2
Atoms are circular	Because the shape of an atom likes sphere	56	12	62.5	4.2
	Because the shape of an atom is flat	20	4	12.5	-
	Because the shape of an atom likes a dot	16	-	12.5	-
All of the atoms are identical	Because all atoms of the elements are the same	36	12	33.3	-
	Because all of the matters in nature consist of the same atoms	24	-	16.7	-
	Because the atoms of the iron are harder than the ones in copper	24	-	25	-
The tap water is pure	Because it includes only one matter	64	16	53.8	4.2
	Because it consists of water atoms	12	4	16.7	-
	Because it is formed by the combination of pure matters	16	-	12.5	-
Whether the matters are mixture or not	Because they are formed by the combination of two different elements	12	-	16.7	4.2
	Because all the mixtures contain the same kind of particles	56	12	50	8.3
	Because they are pure matters	12	-	20.8	-
Whether the matters are compound or not	Because the smallest basic unit of the both models is atom	20	4	12.5	-
	Because the compound are formed by the combination of two identical atoms	40	4	50	8.3

	Because the compounds are formed by the combination of two matters	16	-	20.8	-
Mixtures	The solid powdered beverage melts because it will become liquid	48	4	41.7	-
	It would melt away because a new matter is formed	20	-	16.7	-
	The powdered drink would disappear	20	4	33.3	4.2
The ionic and the covalent bonding	Ionic bonding, because it is formed between two different atoms	28	4	12.5	4.2
	Ionic bonding, because there is an electron exchange among atoms	24	8	34.5	-
	Covalent bonding, because the electronegativity of the fluorine is more than the hydrogen	24	-	29.1	-

The most common alternative conception encountered in pre-test is that the tap water is pure because it includes only one matter. While 64% of the control group students have this alternative conception in pre-test, 53.8% of the experimental group students have this one. After the implementation process, 16% of the control group students have this alternative conception while 4.2% of the experimental group students have this one in post-test. Another most common alternative conception is that atoms are circular because the shape of an atom likes sphere. While 56% of the control group students have this alternative conception in pre-test, 62.5% of the experimental group students have this one. After the implementation process, 12% of the control group students have this alternative conception while 4.2% of the experimental group students have this one in post-test. The other common alternative conception encountered in pre-test is that the matters are mixtures because all the mixtures contain the same kind of particles. While 56% of the control group students have this alternative conception in pre-test, 50% of the experimental group students have this one. In post-test, 12% of the control group students have this alternative conception while 8.3% of the experimental group students have this one. One of the common alternative conceptions encountered in pre-test is that the atom is visible because the microscope enlarges the small particles. While 52% of the control group students have this alternative conception in pre-test, 45.8% of the experimental group students have this one. In post-test, 12% of the control group students have this alternative conception while 4.2% of the experimental group students have this one. Another common alternative conception found in pre-test is that the atomic models are real because the scientists see atoms and draw their models. While 52% of the control group students have this alternative conception in pre-test, 50% of the experimental group students have this one. In post-test, 8% of the control group students have this alternative conception while 4.2% of the experimental group students have this one. One of the alternative conceptions determined in pre-test is that the solid powdered beverage melts because it will become liquid. While 48% of the control group students have this alternative conception in pre-test, 41.7% of the experimental group students have this one. After the implementation process, 4% of the control group students have this alternative conception while the experimental group students dispel this alternative conception entirely in post-test. Another alternative conception is that all atoms are identical because all atoms of the elements are the same. While 36% of the control group students have this alternative conception in pre-test, 33.3% of the experimental group students have this one. After the implementation process, 12% of the control group students have this alternative conception while the experimental group students dispel this alternative conception entirely in post-test. One of the alternative conceptions found in pre-test is that if a matter is crushed, its atoms are also crushed because after the process of crashing, the volume of the atoms would decrease and their shapes would change. While 32% of the control group students have this alternative conception in pre-test, 21.9% of the experimental group students have this one. After the implementation process, both the control and the experimental group students dispel this alternative conception entirely in post-test.

Some of the alternative conceptions encountered in pre-test with lower rates dispelled entirely in post-test. For example, while 12% of the control group students and 20.8% of the experimental group students believe that the atom is visible because there are the shapes of atoms in books; both groups' students corrected this alternative conception entirely in post-test. Another is that, while 24% of the control group students and 16.7% of the experimental group students believe that all of the atoms are identical because all of the matters in nature consist of the same atoms; both groups' students dispelled this alternative conception entirely in post-test. Similarly, while 24% of the control group students and 25% of the experimental group students believe that all of the atoms are identical because the atoms of the iron are harder than the ones in copper; both groups' students dispelled this alternative conception

entirely in post-test. Another alternative conception dispelled entirely in post-test by both groups is that if a matter is crushed, its atoms are also crushed because with the process of crashing atoms would get thinner and longer. 20% of the control group students and 12.5% of the experimental group students have this alternative conception in pre-test. 16% of the control group students and 12.5 of the experimental group students have another alternative conception in pre-test, which atoms are circular because the shape of an atom likes a dot. Both groups' students dispelled this alternative conception in post-test. In pre-test 16% of the control group students and 12.5% of the experimental group students have the alternative conception that the atomic models are real because the models are drawn with the help of microscope. This alternative conception was dispelled entirely in post-test by both groups' students.

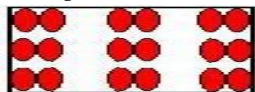
b) Results Obtained from the Interviews

Conceptions regarding the subjects in research were tried to be determined during the interviews conducted after the application with the students chosen from the experimental group, and by this way the findings of the test results were intended to be supported. The examples regarding the students' answers in three categories to the questions during the interview are presented in Table 4.

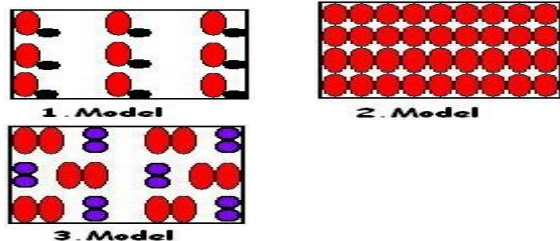
Table 4. Examples Regarding the Students' Answers Organized in Three Categories

Questions	Categories	Answer Samples
1. Matters are seen as a whole when looked at. How do you think the structure of matter is like? Why?	Alternative conception	Matters are in a single shape and therefore they look as a whole (S11)
	Partial understanding	There are atoms in matters, because they stand together, matters look as a whole (S21)
	Correct understanding	Matters consist of atoms. Because we cannot see the atoms through our eyes, we see matters as a whole (S2, S4, S7, S13, S16, S20, S24)
2. If we hammer an iron bar and flatten its shape, what kind of a change occurs in the atoms? For instance, is it possible that the atoms are smashed?	Alternative conception	As matters can be smashed so can atoms (S13)
	Partial understanding	As we do not know the shapes of the atoms, we cannot talk about their being smashed (S20)
	Correct understanding	Atoms cannot be smashed, if they could, there would be big explosions like atomic explosions (S2, S4, S7, S11, S16, S21, S24).
3. If we divided an aluminum plaque or a copper plate in two by scissors, is it possible that we could also divide the atoms there?	Alternative conception	We divide the matters in two by cutting them by scissors. We can also divide the atoms there (S11)
	Partial understanding	---
	Correct understanding	Atoms cannot be divided easily. If they could, there would be big explosions (S2, S4, S7, S13, S16, S20, S21, S24)
4. We know that some of the matters in our environment are soft and some of them are hard. Do atoms have the feature of being soft or hard? Why?	Alternative conception	---
	Partial understanding	We cannot know if the atoms are soft or hard because we cannot see them (S21, S24)
	Correct understanding	Atoms do not have physical features. Softness and hardness depend on atomic bonds and gaps (S2, S4, S7, S11, S13, S16, S20)
5. Imagine that you have two pieces of iron in different sizes. And assume that you take an atom from each of them. Would the size of the atoms you have taken be different too? How do you think the iron atoms are like in shape and size?	Alternative conception	We cannot see atoms. But the iron in bigger size is supposed to have bigger atoms (S21)
	Partial understanding	---
	Correct understanding	Because they are the same matter, the atoms are the same. The size and the shapes of the same atoms are the same (S2, S4, S7, S11, S13, S16, S20, S24)
6. Cell is the smallest unit of the living beings. A cell is like an atom with its nucleus in the middle and its movement. What can you say about an atom being living or not?	Alternative conception	---
	Partial understanding	Atoms are not alive because the matters that are formed by atoms are not alive (S11)
	Correct understanding	Atoms do not have the feature of being alive. They just move. Therefore atoms are not alive (S2, S4, S7, S13, S16, S20, S21, S24)

7. Matters are colorful. Are atoms also colorful? Why?	Alternative conception	It is the atom that gives a matter its color. Gold is yellow, because its atom is yellow (S4)
	Partial understanding	---
	Correct understanding	Atoms do not have colors. Color is related to the matter's reflecting the light, not to the atoms (S2, S7, S11, S13, S16, S20, S21, S24)
8. How is the structure of an atom?	Alternative conception	Atoms are in the shape of a sphere. Because they are demonstrated like that in books (S20)
	Partial understanding	---
	Correct understanding	Every atom is different from each other. As we cannot see atoms, we cannot have an idea about their shape (S2, S4, S7, S11, S13, S16, S21, S24)
9. What is ionic and covalent bonding? What kind of differences are there between them?	Alternative conception	---
	Partial understanding	Ionic and covalent bonds are inter-atomic bonds that hold the atoms together. Both of them hold the atoms together (S11, S24)
	Correct understanding	They are inter-atomic bonds. Ionic bonding takes place between a metal and non-metal via electron exchange. And the covalent bonding occurs by sharing of electrons of two non-metal (S2, S4, S7, S13, S16, S20, S21)
10. What is a homogenous or heterogeneous mixture? Do the chemical features of the matters change in mixtures?	Alternative conception	---
	Partial understanding	The mixtures that show the same features in each part of it are called homogenous mixtures. The mixtures in which the particles can be seen through naked eyes are called heterogeneous mixtures (S13, S20)
	Correct understanding	The mixtures that show the same features in each part of it are called homogenous and that shows different features are called heterogeneous. The matters in mixtures do not change their chemical features (S2, S4, S7, S11, S16, S21, S24)
11. Can you define the pure matter? Which model or models is/are pure matter/s?	Alternative conception	Model 1 is pure matter. Because it consists of the same kind of atoms (S11)
	Partial understanding	Model 1 is pure matter. Because the pure matter is the one which does not include different kind of matters. In model 1 there is not any different kind of atom so it is a pure matter (S21)
	Correct understanding	Model 1 and Model 3 are pure matters. Because these models are formed by the same kind of atoms (S2, S4, S7, S13, S16, S20, S24)



12. What is a compound? Which model or models is/are compound/s?



Alternative conception

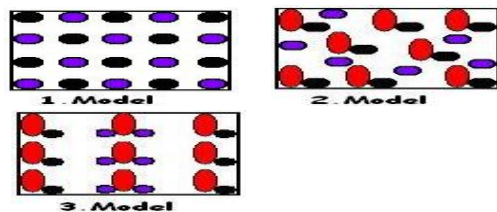
Model 1 and model 3 are compounds, because there are different kinds of atoms (S11)

Partial understanding

Correct understanding

Model 1 is compound, because the compounds must include the same kind of molecules. Only in Model, there are the same kind of molecules (S2, S4, S7, S13, S16, S20, S21, S24)

13. Which model/s is/are mixture/s?



Alternative conception

Partial understanding

Model 2 and model 3 are mixtures. A mixture is formed by different matters' coexisting. In model 2 and model 3 different matters coexist so model 2 and model 3 are compounds (S13)

Correct understanding

All of them are mixture. Different atoms and compounds' existing together is called a mixture. In each model different kinds of atoms and molecules coexist (S2, S4, S7, S11, S16, S20, S21, S24)

Data obtained from the interviews shows that while the rate of the answers given in the category of correct understanding by the experimental group is high, and the rate of the students' answers in partial understanding and alternative conception categories is low. The findings obtained both from the concept test and the interviews has shown that the teaching based on the concept cartoons in the experimental group was much more effective than the control group in students' understanding the concepts regarding the subject the structure and the properties of the matter. And also, experimental group students have better performance in altering the alternative conceptions.

In interviews, thirteen questions were asked to students related to structure and properties of matter after the implementation. The analysis of the interviews show that the rate of correct understanding of the students are generally high while some of the students have partial understanding and some of them still have alternative conceptions after the implementation. The first question of the interview was related to the holistic structure of the matter. In this question, while seven of the students have correct understanding, one student has partial understanding and one student has alternative conceptions. The second question was related to the interchangeability of the shapes of atoms with physical effects. While seven of the students responded the question correctly, one student has partial understanding and one student has alternative conception in this question. The third question was related to the divisibility of the atoms. In this question, eight of the students responded the question correctly stating that atoms cannot be divided. One student has alternative conception. This student believes that we divide the matters in two. We can divide the atoms by cutting them by scissors. The fourth question was related to hardness and softness of the atoms. While six of the students have correct understanding in this question, two students have partial understanding. These students think that we cannot know that they are soft or hard because we cannot see the atoms. There is no alternative conception in this question. The fifth question was related to the properties of the atoms of different sized species of the same matter. While eight students have correct understanding in this question, one student has alternative conception. This student believes that the atoms of the large-sized matters will also be large sized than the small-sized ones. The sixth question asked to the students that whether the atoms alive or not. While eight of the students responded the question in correct understanding category, one student had partial understanding. This student believes that atoms are not alive because the matters that are formed by atoms are not alive. The seventh question was related to colorfulness of the atoms. In this question, eight of the students have correct understanding, one student has alternative conception stating that if a matter is colorful, and its atoms are also colorful. The eighth question was related to the structure of atom. Eight of the students responded this question in correct understanding category while one student had alternative conception. This student believes that atoms are in the shape of sphere. The ninth question was related to the differences between ionic and covalent bonding. While seven of the students had correct understanding in this question, two students had partial understanding. The tenth question was related to homogenous and heterogeneous mixtures. In this question, seven of the students had correct understanding while two of them had partial understanding. These students defined the homogenous mixtures correctly, but they believed that the mixtures in which the particles can be seen through naked eyes are called heterogeneous mixtures. The eleventh question was related to the pure matter. In this question, students were given three different models and asked them to that which one of them represented the pure matter correctly. Seven of the students responded to the question in correct understanding category while one of them had partial understanding. One student had alternative conception in this question. The twelfth question was related to the compound. In this question, students were given three different models and asked them to that which one of them represented a compound correctly. Eight of the students responded to the question in

correct understanding category while one of them had alternative conception in this question. The thirteenth question was related to the mixture. In this question, students were given three different models and asked them to that which one of them represented a mixture correctly. Eight of the students responded to the question in correct understanding category while one of them had partial understanding in this question.

RESULTS, DISCUSSION AND CONCLUSION

The findings of the study show that the students in the grade 7 have some alternative conceptions regarding the subjects in the structure and the properties of the matter and that the concept cartoons are successful materials in identifying and correcting these alternative conceptions.

The leading alternative conceptions of the students are the ones related to atoms. It is observed by their answers in the test that both control and experimental group students think that atoms can be seen. The microscope's magnifying the objects that cannot be seen through naked eyes and making it possible for us to see the objects may be considered the reason of the alternative conceptions. One of the alternative conceptions seen in high rate in the pre-test both groups is related to the atomic models. Most of the students think that the atomic models are real. One of the most important reasons for this alternative conception may be considered as the text book's not including sufficient notice on the subject of atomic models. These models have been put forward to make atoms more comprehensible and they are not real but real-like suppositions. But in earlier studies, it is determined that most of the students described models as the copies of the originals (Bektaş, 2003; Çakmak, 2009; Harrison & Treagust, 1996).

Another alternative conception identified in the study is about the physical properties of atoms. Most of the students in both groups think that atoms have physical properties. The matters' being able to be crushed or cut, in other words, to be exposed to a physical phenomenon is considered as the reason why the students have this alternative conception. In addition, as atoms are the smallest units of matters, it may be considered that the shape of the matter changes because the shape of the atoms has changed. The studies encountered in the literature have also shown the similar results (Abraham, Grzybowski, Renner & Marek, 1992; Çakmak, 2009; Tezcan & Çelik, 2009).

Another alternative conception observed in students is about atoms being similar to each other. Because atoms are too tiny to see with naked eyes, these kinds of alternative conceptions come up about the size of atoms. And the studies in the literature have also shown the similar results (Çakmak, 2009; Griffiths & Preston, 1992; Yavuz, 2005; Yeğnidemir, 2000). Yeğnidemir (2000) has tried to correct this alternative conception with the activities, but he couldn't completely correct it. And as a reason for this, he put forward the concepts' being abstract.

It is observed in the study that the students knew the subjects in theory or as definitions but they were not competent enough to use this knowledge. For instance, although the students could define the concepts as element, compound and mixture, they couldn't demonstrate it on models. This shows that the students are still in knowledge level and that the conceptual learning has not occurred. Most of the alternative conceptions in students results from the fact that they think of microscopic phenomenon in macroscopic level. These conceptions' being microscopic and requiring conceptual thinking has revealed incompetence in students. To overcome the incompetence and to correct the alternative conceptions, concept cartoons are found to be sufficient. This shows that using concept cartoons in the teaching process of abstract concepts may be an effective way.

The concept cartoons' being humorous (Keogh & Naylor, 1999; Uğurel & Morali, 2006) and visual makes the teaching effective. Also, the cartoons' being enjoyable increases

the students' interests in the lesson and makes it easier for students to be motivated (Keogh & Naylor, 1996). Because the speeches in the cartoons are daily and humorous, students understand the concepts better, and they are affected positively during the learning process (Karpudewan, MdZain & Chandrasegaran, 2017). This shows that the lesson's being enjoyable is important in the effectiveness of the teaching process. Presenting the correct concept along with the alternative conceptions helped students to realize their alternative conceptions and prevented others to occur beforehand. And this has also shown that using the materials that shows and states the alternative conceptions is vital in the teaching process.

In addition, although the teaching that is conducted with concept cartoons alters the students' alternative conceptions in a certain level, it is observed that some of them were still present after the application. This supports the idea that even though the materials are prepared directly for the alternative conceptions, it is not easy to correct them and the students' ideas are resistant to change (Küçüközer & Kocakulah, 2007).

In conclusion, it is determined during the application process that the students had numerous alternative conceptions and they were tried to be corrected through concept cartoons. By means of the concept cartoons, the abstract concepts that gained visuality and tangibility were learned correctly by the students and owing to the fact that the cartoons include the alternative conceptions the students were prevented to have other ones. By this means, a more effective teaching was conducted in the experimental group. But preparing a cartoon for more than one learning outcome has affected the teaching negatively at the least. For instance, in the cartoon series in which the concept of the compound is also mentioned, mentioning the other concepts as well has prevented focusing on the conception of compound and teaching the "compound" to the students effectively. In addition, not mentioning about the pure matters sufficiently in the concept cartoons that are prepared about for the solutions caused not being able to correct the alternative conceptions of pure matter. This revealed that every concept cartoons to be prepared must serve for only one concept. By this means, the teaching is considered to be more effective. The informal observations on the experimental group's students by the researchers during the application have shown that the students enjoyed the teaching with the concept cartoons more. And this increased the students' attending the lesson. The cartoons being humorous and including the students' alternative conceptions encouraged the students to express their ideas and provided a good platform. By this means the students realized their alternative conceptions as well as realizing their peers'. The suggestions below could be made in accordance with the results obtained from this study:

- It may be possible to make the lesson enjoyable and make the students like it by means of the cartoons.
- One can benefit from the cartoons when preparing the textbook at a level that students could enjoy and be satisfied.
- Activity books can be prepared that includes cartoons teachers could benefit from.
- Concept cartoons could be used in embodying the abstract concepts and transferring them to the students.
- One can benefit from the concept cartoons when trying to encourage the shy students to attend the lesson and share their ideas.
- A comfortable platform is provided through the concept cartoons and by this means students become aware of the other students' ideas.

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Experimental Group		Control Group	
Teacher's role	Students' role	Teacher's role	Students' role
<ul style="list-style-type: none"> ❖ The teacher reflected the first cartoon series on the blackboard through the OHP. ❖ After reading and summarizing the cases in the cartoons, he wanted students to find the right concepts ❖ He explained the concepts; atom, element and compound and gave examples ❖ After that, he asked the reason why the right concepts are right, and the wrong ones are wrong on the 1st cartoon series 	<ul style="list-style-type: none"> ❖ They read the 1st cartoon series ❖ They tried to find the right and the wrong concepts through discussion ❖ After that, they discussed the reason why they are right or wrong. 	<ul style="list-style-type: none"> ❖ The teacher came into the class with salt (NaCl) in his hand and asked the students what it is made up and how it is made up. ❖ He wrote the definitions of atom, element and compound on the blackboard and gave examples. ❖ He asked students to give examples of matters they experience in daily life and tell if they are element or compound. ❖ He asked the difference between an element and a compound. 	<ul style="list-style-type: none"> ❖ They tried to find out what the salt is made up through discussion. ❖ They gave examples of element and compound from daily life. ❖ They tried to find out the difference between an element and a compound.
<ul style="list-style-type: none"> ❖ The teacher reflected the second cartoon series on the blackboard through the OHP. ❖ After reading the cases in the cartoons, he asked students to decide which students gave the right answer. ❖ He explained the inter-atomic bond and that they cannot dispel it with physical process. He stated that the atoms of different matters that are made up of the same atoms would be the same and gave examples. ❖ He asked students to explain the reason why the wrong answers are wrong. 	<ul style="list-style-type: none"> ❖ They read the 2nd cartoon series. ❖ They tried to imagine the cases in the cartoons ❖ They tried to find the right concept through discussing ❖ After that they discussed the reason why the concepts are right and wrong 	<ul style="list-style-type: none"> ❖ The teacher cut the paper in two and asked "How did it divide into two? Have I cut the atoms of the paper?" ❖ He talked about the inter-atomic bond briefly and explained that they cannot be divided by physical intervention ❖ He gave the example that when they mash the salt (NaCl), it doesn't turn into Na and Cl. ❖ And after that he asked the students whether all the atoms are the same or not. ❖ He mentioned that the same types of atoms are the same and asked the students to summarize the lesson. 	<ul style="list-style-type: none"> ❖ They tried to tell how the paper is divided into two with the help of their prior knowledge. ❖ Discussing, they tried to find out that even if their shapes are different, the same matters have the same kind of atoms. ❖ They tried to summarize what they have learned about this subject.

<ul style="list-style-type: none"> ❖ The teacher reflected the third cartoon series on the blackboard through the OHP. ❖ He introduced the cartoons and read the speech on the cartoons. ❖ He explained the historical development of the atomic model and how it was found. ❖ He asked students to tell the deficiencies of models with the help of the statements on the cartoons. 	<ul style="list-style-type: none"> ❖ They read the third cartoon series ❖ They tried to figure out how the atomic models became evident. ❖ Discussing, they tried to find out the deficiencies in the models 	<ul style="list-style-type: none"> ❖ The teacher drew the atomic models on the board according to their historical order. ❖ After that, he explained which atomic model was found by whom and how it was found. ❖ He sorted the deficiencies of the atomic models as items ❖ He asked students to take notes of these deficiencies 	<ul style="list-style-type: none"> ❖ Students took notes of the atomic models and their deficiencies according to their historical order.
<ul style="list-style-type: none"> ❖ The teacher reflected the fourth cartoon series on the blackboard through the OHP. ❖ He read the speeches and summarized the case in the cartoon. ❖ He drew two atoms making ionic bond and explained what it is, and he asked students to associate it with the case in the cartoon. ❖ After that, he asked students to find the student in the cartoon who has explained the concept correctly. ❖ He explained the ionic bond on the cartoons and he likened students' giving money to each other to atoms' giving electrons. ❖ He gave daily examples 	<ul style="list-style-type: none"> ❖ They read the 4th cartoon series. ❖ They tried to associate the ionic bond with the case on the cartoons. ❖ They tried to find out which student's idea in the cartoon is correct through discussing. 	<ul style="list-style-type: none"> ❖ He drew on the blackboard how the water (H_2O) makes bond. ❖ After that, he explained to the students that atoms could make bonds giving their electron to each other and added that was called the ionic bond. ❖ He talked about the metallic and non-metallic bonds and stated that metallic and non-metallic compounds are stable with ionic bond ❖ He gave examples of ionic-bonded compounds from daily life. ❖ Summarizing the subject, he made the students write it down. 	<ul style="list-style-type: none"> ❖ They tried to figure out what the ionic bond was. ❖ They learned which of the compounds from the daily life were formed by ionic bond. ❖ They took notes.
<ul style="list-style-type: none"> ❖ The teacher reflected the fifth cartoon series on the blackboard through the OHP. ❖ He read the speeches and summarized the case in the cartoon. ❖ He drew two atoms making covalent 	<ul style="list-style-type: none"> ❖ They read the 5th cartoon series. ❖ They tried to associate the covalent bond with the case on the cartoons. ❖ They tried to find out which student's idea in the cartoon is correct through discussing. 	<ul style="list-style-type: none"> ❖ The teacher summarized the ionic bond. ❖ After that, he added that atoms could be in conjunction with each other sharing their electrons commonly. 	<ul style="list-style-type: none"> ❖ They tried to understand what the covalent bonding was. ❖ They learned the compounds formed by covalent bonding and how they were formed. ❖ They took notes.

<p>bond and illustrated the covalent bonding and asked students to associate it with the case in the cartoon.</p> <ul style="list-style-type: none"> ❖ After that, he asked students to find the student in the cartoon who has explained the concept correctly. ❖ He explained the covalent bond on cartoons and likened students' sharing their money to buy a ball to atoms' sharing their electrons. ❖ He gave daily examples. 		<ul style="list-style-type: none"> ❖ He drew a compound on the black boards as an example for cooperation of electrons and illustrated the covalent bonding. ❖ He summarized the subject and asked students to take notes. ❖ He asked students to tell the difference between the covalent and the ionic bond. 	<ul style="list-style-type: none"> ❖ They tried to tell the difference between the covalent and ionic bond.
<ul style="list-style-type: none"> ❖ The teacher reflected the sixth cartoon series on the blackboard through the OHP. ❖ He summarized the case in the cartoon and read the speeches. ❖ He asked students' idea about the homogenous and heterogeneous mixtures and then explained the homogenous and the heterogeneous mixtures. ❖ After that, turning back to the cartoons, he asked which students tell the truth. ❖ He asked students to give daily examples. 	<ul style="list-style-type: none"> ❖ They read the 6th cartoon series. ❖ They shared their idea on the homogenous and the heterogeneous mixtures. ❖ They tried to find out which students' ideas in the cartoon were correct through discussing. ❖ They gave examples of homogenous and heterogeneous mixtures. 	<ul style="list-style-type: none"> ❖ The teacher explained the mixtures and gave examples. ❖ He stated that there were different kinds of mixtures, two of which were homogenous and heterogeneous. ❖ He explained how homogenous and heterogeneous mixtures were formed. ❖ He asked the students to tell the difference between the homogenous and the heterogeneous mixtures. ❖ He asked students to give examples of homogenous and heterogeneous mixtures. 	<ul style="list-style-type: none"> ❖ They tried to understand how homogenous and heterogeneous mixtures were formed. ❖ They tried to tell the difference between the homogenous and heterogeneous mixtures. ❖ They tried to give examples of homogenous and heterogeneous mixtures from daily life.

ARGUMENTATION BASED INQUIRY APPLICATIONS: SMALL GROUP DISCUSSIONS OF STUDENTS WITH DIFFERENT LEVELS OF SUCCESS

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ABSTRACT

The aim of this study is to investigate experiences of groups with different success levels during small group discussions in argumentation applications. In the study, case study was based as one of qualitative research patterns. In this line, a success test including mechanical subjects comprising multiple-choice and open-ended questions was applied to students by researches in the beginning of semester. Looking at points taken from the success test, student levels (high, medium and low) were determined and groups were formed in accordance with these levels. Argumentation based inquiry was carried out in “force and effect” subject. Study group consisted of 10 preservice teachers having education in Department of Science Teaching. Voice records of every group were taken during student discussions and analyzed by transcription. Codes prepared by the researches were combined under certain categories and entitled. Results show that students with all success levels were physically and mentally active, the argumentation process was effective and the process contributed to students in terms of reasoning, thinking like a scientist and understanding the scientific process in during small group discussions. Moreover, when student-student questions were examined, there were more questions in high level group than others group.

Keywords: Argumentation, Argumentation based inquiry, Small group discussion.

INTRODUCTION

There is an increasing trend bringing thoughts on how the scientific information is structured and how arguments contribute to the process of scientific information structuring together (Erduran, 2007). It has been accepted by educators that inquiry is very important to reach new information (Ford, 2008). There are many definitions available for inquiry. Inquiry is also mentioned in American National Science Education Standards (NRC, 1996; p.23):

“Inquiry is a multifaceted activity that involves making observations; posing question; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental



evidence; using tools to gather, analyze, and interpret data; proposing answer, explanations, and predictions; and communicating the results.”

Benchmarks describes inquiry as a more complex method than doing experiments or explanations and states that the steady advancement of science depends on the enterprise as a whole (AAAS, 1993). In Turkey, the Ministry of National Education revised the Science teaching program and determined raising individuals with science literacy as the main vision of the program. It was set forth in the curriculum that inquiry process should not be considered as only “exploring and experimenting”, because it also involves the process of “explaining and forming arguments” (Ministry of National Education (MNE), 2013). Inquiry-based learning is a student-oriented learning approach in which students have a desire to explore everything around them, form powerful arguments regarding the natural and physical world around them, become individuals who are passionate about and value science, in short, obtain knowledge by behaving, living, and thinking like scientists (MNE, 2013).

In the light of definitions regarding inquiry, Erduran (2007) notes that inquiry should not only be handled as a part of the curriculum, but roles of students and teachers in the learning environment should also be defined. In inquiry-based science courses, students deal with the solution of the actual scientific problem, which involves thinking about research topics (Polman & Pea, 2001). In this way, they gain experience by living the process experienced by scientists. Moreover, learners design their own activities and process information, not only memorize it. In the process, the teacher does not transfers information or manage the student, but assumes the role of a guide (Duschl & Osborne, 2002) who facilitates thinking for the student (Anderson, 2002), allows the student to experience the responsibility and excitement of reaching scientific information, encourages the formation of scientific thinking (MNE, 2013), provides the skill of reasoning and guides the research process with questions (Chen, Hand & Benus, 2014).

It is important to organize classes as educational environments providing opportunities that involve inquiry applications and systems that require thinking (Grandy & Duschl, 2007). The curriculum, the teacher and the environment must be in cooperation to this end. Argumentation allows for a learning environment that structures epistemic aspects of inquiry and guides students in forming and assessing scientific explanations (Sandoval & Reiser, 2004). According to Driver et al. (2000), scientific discussions in science courses have four goals: to improve conceptual understanding of students, to improve research ability of students, to improve scientific epistemology, and help students to recognize science as a social practice. As well as making it possible for epistemology of scientific information to be understood better, argumentation allows for a better conceptual understanding of science as well (Osborne, 2005). Argumentation has a central role in science education especially in terms of developing conceptual understanding, improving inquiry skills of students and improving students’ understanding of scientific epistemology, thus it is important to include argumentation in science education (Driver, Newton & Osborne, 2000; Chin & Osborne, 2010).

Toulmin (1958) states that arguments are generally logical inferences based on specific information and describes argumentation as students coming up with claims based on quantitative or qualitative data, evidence or theoretical knowledge and presenting evidence on which the claim is based. According to Driver et al. (2000), argumentation is an activity performed via thinking and writing individually or in groups. Fundamentally, science is defined as social activities based on scientific discussions (Kuhn, 1991). Students who engage in these activities form meaningful scientific concepts and understand how a scientist improve the natural world (Hofstein & Lunetta, 2004). Argumentation is also defined as the process of convincing people of the validity of a certain claim (Toulmin, 1958). It is possible to say

based on various definitions of argumentation that it is usually perceived as a dialogical activity that allows people to discuss their ideas (Chin & Osborne, 2010). In this process, students respond to claims of others, make explanations, ask questions and prove the opposite to rebuttal alternative ideas. When students ask questions regarding things which they desire to know, they come to realize what they do not know or become amazed or surprised about these things. Being asked questions or witnessing their peers being asked questions allow them to structure their own thoughts by playing a “thought-starter” and metacognitive or epistemic role (Chin & Osborne, 2010). Moreover, argumentation can take place in individuals’ minds as a part of reflective and rational discourse. In classes where argumentation is used, students focus on using theories, data and evidences to form and rebuttal claims (Simon, Erduran, & Osborne, 2006).

Since the beginning of the 1990s in particular, the role of language and communication (speaking or writing) in classroom and structuring of scientific knowledge has been recognized. For example, “Science as Inquiry Standard” highlights the importance of students’ understanding of what and how we know through science (Erduran, 2007). Argumentation Based Science Learning is one of the approaches that describe the nature of the science as inquiry and argument, guide students with activities, serve as a metacognitive support to encourage students to reasoning based on data and involve a writing activity that engage both the student and the teacher (Akkus, Gunel & Hand, 2007). Researchers have developed this approach, originally known as *Science Writing Heuristic (SWH)*, to support writing as a form of thinking in science class (Hand & Keys, 1999). However, recent studies emphasize that argumentation is in the nature of the SWH approach (Hand, 2008; Kabataş Memiş & Seven, 2015). SWH is a writing tool involving thought-support, meaningful discussion and science laboratory activities (Hand, Wallace & Yang, 2004).

The SWH approach help students develop a deeper understanding about big ideas related to science content with stages of student template/plan that involve asking and analyzing questions, comparing ideas with others and reviewing how ideas change throughout the process (Akkus, Gunel & Hand, 2007). The SWH approach involves cognition and metacognition approaches for science learning and allow students to blend processes such as making connections between data, method, evidence and claim and formulating and supporting claims in their writing (Hohenshell, 2008). Since the SWH approach involves standard forms such as establishing relations between claims and evidences, it allows students to improve their conceptual understanding (Akkus, Günel & Hand, 2007). The template aimed at teachers represents the pedagogical dimension of the approach, whereas the template aimed at students represent the learning dimension (Günel, Omar & Hand, 2003). The student template and the teacher template can be seen in Table 1. (Hand, Wallace & Yang, 2004) .

Table 1. The two templates for the SWH: the teacher template and the student template

The science writing Heuristic, Part I: A template for teacher –designed activities to promote laboratory understanding	The science writing Heuristic, Part II: A template for students
1. Exploration of pre-instructional understanding (e.g. individual or group concept mapping).	1. Beginning Ideas – What are my questions?
2. Pre-instructional activities (e.g. informal writing, making observations, brainstorming, and posing questions).	2. Tests – What did I do?
3. Participation in science activity.	3. Observations – What did I see?
4. Negotiation phase I – writing personal meanings for science activity (e.g. writing journals).	4. Claims – What can I claim?

5. Negotiation phase II – sharing and comparing data interpretations in small groups (e.g. making a group chart).	5. Evidence – How do I know? Why am I making these claims?
6. Negotiation phase III – comparing science ideas to textbooks or other printed resources (e.g. writing group notes in response to focus questions).	6. Reading – How do my ideas compare with others?
7. Negotiation phase IV – individual reflection and writing (e.g. creating a presentation such as a poster or report for a larger audience).	7. Reflection – How have my ideas changed?
8. Exploration of post-instructional understanding through concept mapping.	

In the literature, there are both national and international studies performed using the ABI approach and different topics. In these studies, topics such as academic achievement of prospective teachers (Erkol, Kışoğlu & Büyükkasap, 2010; Günel *et al.*, 2010; Hand *et al.*, 2004), success of students (Hand & Keys, 1999; Hand *et al.*, 2004; Keys, Hand, Prain & Collins, 1999; Kırır, Geban & Günel, 2011), student-student/ teacher-student questions (Chin & Osborne, 2010; Günel, Kırır & Geban, 2012), success levels Akkuş, Günel & Hand, 2007; Grimberg & Hand, 2009; Kırır, 2011; Kırır, Geban & Günel, 2012), pre-service teacher education (Aydın & Kaptan, 2014) are handled. Günel *et al.* (2010) investigated the effect of the ABI approach on success of university students in general physics laboratory course and showed that the ABI group was more successful compared to the other group in terms of post-test scores related to mechanics subjects. Similarly, it was seen in a study conducted by Hand, Wallace and Yang (2004) that students who used the SWH approach were more successful in science subjects compared to those who did not. It is important to ask quality questions at every stage (beginning, continuation and conclusion) or this discussion process. Chin and Osborne (2010), who aimed to investigate the qualities of student questions which support argumentation, stated that there were different interactions between groups and concluded that questions were essential and important for discussion. Günel, Kırır and Geban (2012) highlighted that question strategies and implementation level of the teacher was effective on formation and continuation of the discussion process. Among studies on success levels; in the study conducted by Akkuş, Günel and Hand (2007) with 7 teachers instructing in different grades and 592 students, the SWH applications were examined according to implementation levels of teachers and success levels of students. As a result, it was found that SWH applications were effective on success levels of students. It was stated that the approach allowed students to think within the framework of explaining and interpreting science concepts. Another study was conducted by Kırır, Geban and Günel (2012) on effects of the SWH approach on performance of students with different success levels. Findings obtained as a result of the study showed that experimental group (in which the SWH approach was used) students had significantly better test performance/success compared to control group (in which the traditional approach was used) students. Also, it was found that students with different success levels had different post-test success levels. Students with low and moderate success levels had better post-test scores compared to the group in which the traditional approach was used.

Previous studies usually emphasized that the ABI approach was more effective compared to the traditional method, contributed to improvement of conceptual understanding of students with various success levels and it was important to ask questions in the process. However, we were not able to find a study on state of and change experienced by students with different success levels during small group discussions in argumentation applications.

Therefore, the aim of this study is to investigate experiences of groups with different success levels during small group discussions in argumentation applications.

The research question determined for this aim is “How are the groups’ experiences in different success levels during small group discussions in argumentation applications?”

METHODS

The study utilizes the multiple case study design, which is one of the case study patterns (Yıldırım & Şimşek, 1999). Case study is described by researchers (Yıldırım & Şimşek, 2008; Yin, 1984) as an in-depth research method used in situations allowing for investigation of a recent phenomenon in its natural environment. Therefore, this study evaluates students in three different success levels as higher, middle and lower success groups and examines each group (higher, middle and lower) as a unit of analysis.

Participants

The study group consists of 10 prospective teachers selected from 25 prospective teachers attending Science Education program of a medium-scale university located in Northwestern Turkey in fall semester of 2013-2014 academic year. In this context, a success test containing 28 multiple-choice and 7 conceptual questions on mechanics subjects was applied to the students by the researchers in order to determine their success levels. Test questions were selected from different sources (Çolakoğlu, 2002; Hewitt, 2002) appropriate to students’ levels and exams of Student Selection and Placement Center.

Opinions of two faculty members, an expert on physics and an expert on language, were received and necessary corrections were made to ensure validity. At the end of the application, the Cronbach’s Alpha reliability coefficient of the test was found to be .71. An answer-key was created for conceptual questions and answers given by students to conceptual questions were scored by an independent researcher, an expert in physics. The student names were hidden. The distribution of questions in the success test according to cognitive stages can be seen in the table of specifications (Table 2). Success levels of students were determined based on their test scores. When determining success levels, the study conducted by Akkuş, Günel and Hand was used as a reference. Average scores obtained from the test and standard deviations were taken into account for success levels. Accordingly, a score a quarter standard deviation around the mean ($\bar{X} - \frac{1}{4} SD$, $\bar{X} + \frac{1}{4} SD$) was chosen as a medium achievement level (GM), a score a quarter-standard deviation below the mean ($\bar{X} - \frac{1}{4} SD$ and below) was chosen as a low achievement level (GL), and similarly a score a quarter-standard deviation above the mean ($\bar{X} + \frac{1}{4} SD$ and above) was chosen as a high achievement level (GH). There are 7 groups within the scope of the study: 3 groups with 3 students and 4 groups with 4 students. 3 of these groups are in the GL category, 2 groups are in the GM category and 2 groups are in the GH category. One group from each success level was examined within the scope of the study. The GL group contains three students (2 male, 1 female) (coding: Student₁ (S₁), Student₂ (S₂) and Student₃ (S₃)), the GM group contains four students (3 female, 1 male) (coding: Student₄ (S₄), Student₅ (S₅), Student₆ (S₆) and Student₇ (S₇)) and the GH group contains three students (3 female) (coding: Student₈ (S₈), Student₉ (S₉) and Student₁₀ (S₁₀)).

Table 2. *Success Test*

Subject	Cognitive stage					
	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
Ascending force/density		8,11,12,15,18, C3, C4	9,13,14,16, 17	10, C5		
Force and effect		4, 11, C1	1,2,3,5,6,7	10		
Movement		19,20, 21, 22				
Two-dimensional Movement	25	24	23	C6,C7		C2
Energy and energy conservation		26	27, 28, 29			

Note: Multiple choose questions shows as numeric (1,2,3,...), conceptual questions shows as C1, C2,...

Application

For the purpose of the study, the “force and its effects” subject was used. Students learned the selected subject in the Science and Technology Education Laboratory Applications I course, in which the ABI process was applied. Students performed laboratory activities by experiencing argumentation based inquiry process for a semester. Prior to this process, students were encouraged to engage in discussions based on a text containing complex data and evidence in order to allow them to better understand the argumentation process and establish the relation between claim and evidence. The aim was to allow students gain awareness regarding concepts of question, claim and evidence, which constitute the foundation of argumentation. Then, students treated the mechanics subject throughout the semester in line with the argumentation process. The research encouraged students to engage in discussion about a problem related to the subject of the week (subjects were interrelated). Students wrote two questions which they wanted to answer on the board at the beginning of each session as a group. Then, the researchers and students discussed about the quality of questions and what sort of path to follow to answer these questions. Then, the students performed experiments in groups in order to answer these questions, made claims based on obtained data and observations and supported their claims with evidence. Students performed these activities in small group discussions. A voice recorder was used in each group during applications to record discussions between students during the process. In the meantime, the researchers assumed the role of a guide who encourages students to think, make comparisons and control the process. Then, the groups engaged in a larger group discussion in which they shared their findings with the whole class. In this process, each group presented questions which they tried to answer, what path they followed, their observations and data obtained to other groups together with their claims and evidences. In the meantime, other students asked questions related to claims and evidences of the presenting group. When necessary, the researcher asked questions such as “Do you agree with this idea? Why?” in order to allow students to engage in discussion. After presentations of all group were completed, the teacher provided a general summary and gave the problem of the next week. Within the scope of this application, small group discussions on the “force and its effect” subject were assessed. Questions prepared by each group related to the “force and its effect” subject, the process experienced, experimental results and claims are given in Table 3.

Table 3. *The argumentation process of the students*

	Question	Claim	Evidence
GL	Let us assume we have two books with similar thicknesses and sizes. The books have almost the same number of pages, at least 100. How can we find the maximum static force using these two books only?	The force of friction between 2 pages is smaller than the force of friction between 100 pages.	Single pages moved more easily and quickly, whereas interwoven pages did not move at all.
GM	An object is moved on wooden, glass and carpet surfaces. On which surface does this object have a larger force of friction?	The force of friction is the smallest on the glass surface. Because the glass surface is smoother according to our experiments.	In our experiments, the force applied by the object pulled by dynamometer to pull back the dynamometer was the smallest on the glass surface, thus we can say that the force of friction is the smallest on the glass surface.
GH	Explain the effects of two objects with different structures (eraser and a 100g weight) on different surfaces (glass and table).	Effects of two different objects on the same surface or different surfaces will be different. The same force can create different reactions.	A reaction occurs against the effect. However, since surfaces have different structures, they have different reactions. When the same force is applied to different surfaces, different reactions can be obtained due to structural differences between surfaces (hardness, resistance, etc.). Based on their resistance values, the reaction may be frictions on a surface, whereas the other surface may remain undamaged.

Coding and Analyses

Voice recording was used in small group discussions throughout the process and the recordings were transcribed to obtain written documents. Each document was coded separately by three researchers. Then, the researchers came together and assessed codings. During this assessment, the researchers discussed statements which were coded differently by researchers and reached a consensus. Themes were created once the coding process was completed. Since statements of measurement, prediction, classification, conclusion, interpretation, determination of variables, controlling variables, observation, data presentation, giving references, reference to authority, comparison, planning (experiment arrangement), use of foreknowledge, explanation (communication) are indicators of process skills of the students, these codings were placed under the scientific process skills theme. Since processes such as awareness, monitoring and assessment, which are structured metacognitively, involve metacognitive knowledge and activities (Yürük, 2005), codes of indecision, gaining awareness, decision-making and assessment were placed under the metacognition theme. The supporting argumentation process theme was formed by bringing together codes such as argument, evidence, disprove, justification, inquiry, convincing, acceptance-resistance, and cause-effect. The managing the process theme contains statements related to instruction, peer teaching, making suggestions, proposing alternatives, confirmation, asking for confirmation, controlling the understanding and peer support, which are used by individuals to regulate the usual progress of the process. Apart from these four themes, questions asked by the students during the process were also coded separately as low-level questions (Yes or No questions) and high-level questions (questions that require higher-level inquiry). Codes and themes created are handled in the findings section.

FINDINGS

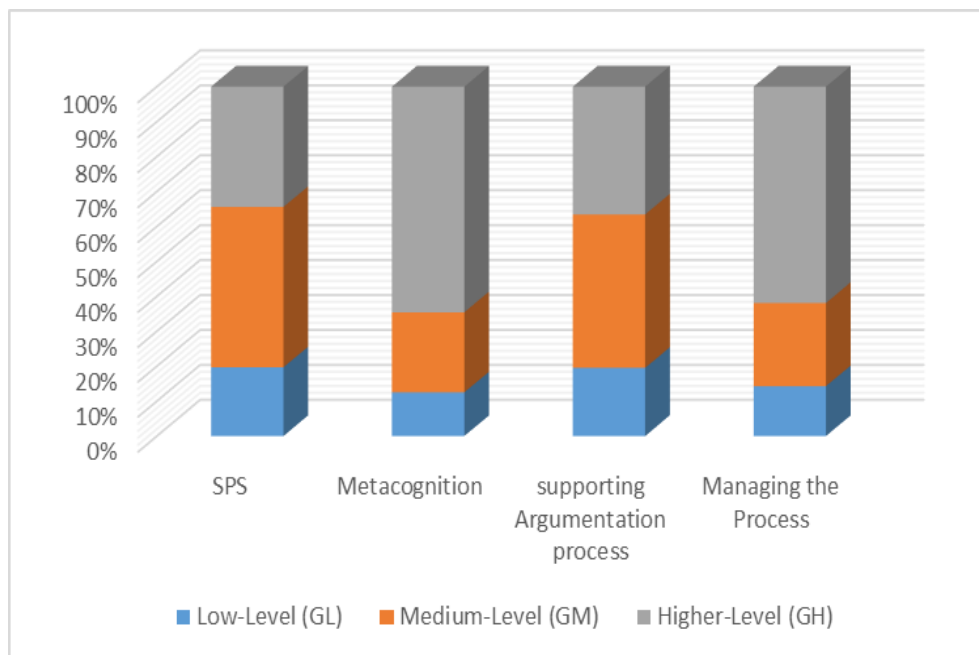
This section contains findings related to the data collected during the research. Themes created following codings determined with analyses and frequencies related to number of codes of each group for each theme can be seen in Table 4.

As seen in Table 4, themes were determined taking into account the processes experienced by the students in small groups (questioning, justification, explaining, explaining, convincing, cause-and-effect relationship, peer teaching, controlling understanding, conspicuousness, decision/indecision, making suggestions, prediction, inference, measurement, etc.). Percentages representing the total number of codes related to first four themes of GH, GM and GL groups can be seen in Graph 1. Findings related to each theme were given with dialogs between students.

Table 4. Themes and Codings

Theme	Coding	Groups		
		GH (f)	GM (f)	GL (f)
Scientific Skills (SPS)	Measurement		2	
	Prediction	2		2
	Inferring	1		
	Interpretation	12		1
	Conclusion	2	7	2
	Controlling variables	1	2	5
	Determination of variables	1		
	Observation		1	
	Data presentation	1	1	
	Giving References	1	2	1
	Reference to authority	11		1
	Comparison	1	2	
	Planning (experiment arrangement)		3	
	Use of foreknowledge	6	4	2
	Explaining	18	4	
Metacognition	Indecision	4		
	Gaining awareness	7	2	1
	Decision-making		1	
	assessment	20	6	
Supporting Agumentation Process	Claim		1	
	Rebuttal	6	2	1
	Justification	10	4	1
	Inquiry	8	6	6
	Convincing		1	
	Resisting	1	1	
	Cause-effect		3	
Managing the Process	Instruction	11	5	1
	Peer teaching	8	5	1
	Making suggestions /	2	7	2

		Proposing alternatives			
		Confirmation	20	12	
		Asking for confirmation	34	5	2
		Controlling the understanding	5	1	
		Peer support	4	1	
Students-questions	students	Low-level question	43	28	22
		High-level question	4	1	7



Graph 1. Results of three different groups related to first four themes

As seen in Chart 1, in terms of the scientific process skills theme, the students in the GH group experienced situations reflecting scientific process skills more frequently compared to the students in the GL group, whereas the students in the GM group experienced situations reflecting scientific process skills more frequently compared to both the GL group and the GH group (45.9%). It was found that the students in the GH group used statements such as “*What did the teacher say? There is the force of friction and also the influence of the gravity.*” which makes a reference to the authority or statements such as “*Girls, what if we put the weight instead of F and say minus 560 multiplied by k , would that give a net force of 120?*” which represents reasoning, whereas the students in the GL used statements such as “*The force of friction is present if there is contact, if there is no contact, the force of friction is zero.*” which reflects making inferences. The Episode 1 shows a sample dialog from small group discussions of the GM group, in which this situation took place most frequently. During the activity where the students in the GM group examined the force of friction by moving an object on different surfaces (wooden, glass, carpet), it was seen that the students used statements such as “*No, we are trying to measure the force of friction on different surfaces, on wood, glass and carpet.*” which indicate controlling variables or statements such as “*Let us do it using the other side.*” or “*We found it to be 2.6 when we moved the object on the carpet and 1 Newton when we moved the object on the wooden surface.*” which reflect inferring.

Episode 1(GM)

- S₄ : The carpet will not slip.*
- S₅ : About 2,5.*
- S₄ : Three, four ...*
- S₆ : Do I need to find it?*
- S₄ : **Let us use the other side (controlling variables)***
- S₅ : Two.*
- S₄ : Two. Okay, that is better.*
- S₇ : You did not pull it quickly. Here, you pulled it quickly.*
- S₆ : Let us put it equally. It says...*
- S₄ : No.*
- S₆ : But their distances are not the same.*
- S₆ : **Aren't we supposed to pull each of them at the same distance? For example, aren't these supposed to have the same size? (controlling variables)***
(The teacher approaches the table...)
- S₇ : What do you use to find the force of friction?*
- S₄ : **No, we are trying to measure the force of friction on different surfaces, on wood, glass and carpet. (explaining)***
(Experiment phase is over...)
- S₄ : **We move on the surface of the carpet and found 2.6. (inferring)***
- S₆ : Yes, Newton.*
- S₄ : Yes, Newton, **we move on the wooden surface and found 1 Newton. (inferring)***

During small group discussions related to the metacognition theme, the students in the GM group experienced situations reflecting indecision, gaining awareness, decision-making and assessment more frequently compared to the students in the GL group, whereas the students in the GH experienced these situations reflecting these metacognitive processes more frequently compared to both the GL group and the GM group (See Graph 1). Statements such as “*It means that it changes...*” which indicate awareness or “*You did not pull it quickly, but here you did.*” which indicate peer assessment were seen more frequently in the GM group. The GH group tried to figure out how to find the maximum static force using two books with similar thicknesses and sizes. A dialog showing statements related to the metacognition theme used during small group discussions of the GH group can be seen in Episode 2. As seen in Excerpt 2, the students in the GH group used metacognitive statements such as “*...We cannot do anything else about it.*”, “*I do not remember this net force*”, “*There is a formula as far as I know but when you include this and that...*” which indicate assessment. These assessment statements were sometimes general assessments, yet it was note-worthy that the students also used self-assessment and peer assessment. Also, as seen in Excerpt 2, the students in this group used statements such as “*But I think it does not cover the action of force. What was F_s ? I guess it was not like this. What should I do?*” indicating indecision, which was experienced more frequently compared to other groups.

Episode 2 (GH)

- S₈ : **f to this direction, f_s to this direction and mg downwards. We cannot do anything else about it. (assessment)***
- S₉ : **I do not remember this net force. (self-assessment)***

- S₁₀ : I mean, we need a primary school text book. But I think it does not cover the action of force. I does cover pressure. Maybe you should check it out. What was Fs? I guess it was not like this. (indecision)*
- S₈ : There is a formula as far as I know but when you include this and that... (assessment)*
- S₁₀ : Here, I think... How do I do that... (indecision)*
Look, since these forces balance each other, we do not need this.

The argumentation process reflects the discussions between students within the framework of question-claim-evidence triangle. During each stage of the small group discussion, students experience situations such as inquiry, cause-effect, resisting, being convinced, using reasoned statements and rebuttal (their own ideas and peer' ideas). Students form their claims and evidences by finding answers to their questions as a result of these inquiries. Considering the findings related to the supporting the argumentation process (Graph 1), it was seen that the GH group and the GM group used statements supporting the argumentation process more frequently compared to the GL group. The GM group used such statements most frequently. It was found that the students in the GH group used statements such as "No, it wouldn't decrease." which indicate confuting, whereas the students in the GL group used similar statements indicating rebuttal such as "Let's assume it is 1, as 1x5, but it won't work like this, it has a friction coefficient." or statements indicating inquiry such as "Now, when we apply forces affecting this, g is downwards, N is upwards, if we assume it does not move, 0.4 does not move as well. Are we supposed to assume it is lower than the threshold value?". A dialog showing statements related to the supporting the argumentation process theme used during small group discussions of the GM group can be seen in Episode 3. It was seen in this discussion Episode that the GM students used statements such as "The rougher the surface is, the higher the friction is." indicating claims and "I mean without applying force." which reflect justification. The group students were also observed to use statements showing the use of cause-effect such as "If the direction of the force changes, the response changes as well." or "Since the weights are the same, there is nothing wrong with comparing them, it is the same thing.". This group can be said to have frequently experienced situations supporting the argumentation process.

Episode 3 (GM)

- S₄ : Everybody, think.*
- S₇ : Okay, I did. The object keeps moving once you pull it. I would keep moving forever.*
- S₄ : The rougher the surface is, the higher the friction is. (claim)*
- S₅ : Okay.*
(The teacher approaches the table...)
- Teacher : I drew it like this, so there is only G downwards. What do we have upwards? There is N and Fy. The sum of two equals this. Now, when I look at this, the value of the force Fy is downwards this time, right? Look, the force is applied as this.*
- S₆ : Yes.*
- Teacher : Downwards, right?*
- S₄ : Yes.*
- S₆ : Yes.*

Teacher : Since it's downwards, the sum of downwards is equal to the sum of those upwards, right?

S₆ : Yes.

Teacher : In this case, $N = F_y + G$. Right?

S₆ : Yes.

Teacher : Then what is F_s ? k.N. What do we mean by N here? Doesn't N change in this case?

S₄ : It means that it changes, Professor.

S₇ : Teacher, I meant without applying force. (justification)

The managing the process theme contains codes such as instruction, peer teaching, making suggestions, proposing alternatives, confirmation, asking for confirmation, controlling the understanding and peer support. The GM students used statements reflecting this theme more frequently compared to the GL group, whereas the GH group used such statements more frequently than other groups (see Graph 1). Especially during the experiment set-up stage of small group discussions, statements reflecting instruction were used quite frequently. For example, the students in the GM group were observed to use statements such as “Look at the one right next to I” or “You read the value and I will write it”, which reflect instruction, when performing a measurement with dynamometer.

Students become responsible for each other's learning in small groups. Students often used statements asking for confirmation such as “isn't it?”, “right?” or “okay?” during their inquiries. The statements of “For example, aren't these supposed to have the same size?” or “ $N = mg$ is the weight, okay?” can be given as an example for the GM group. A sample dialog between the students in the GH group related to the managing the process theme can be seen in Episode 4. It is seen from the dialog that the students in the GH group frequently used statements related to the managing the process theme such as instruction and asking for confirmation.

Episode 4 (GH)

S₁₀ : Girls, we need to find K . We already found mg .

S₉ : What is mg ? Multiplied by K and now it is 560.

S₁₀ : If we assume it is divided by 1, the result is negative for F_{net} , right? The coefficient of friction is usually given zero, how do we find it? (asking for confirmation)

*S₉ : Girls, now we found its weight to be 560. This is a separate value, isn't it? (asking for confirmation)
(When discussing different variables...)*

S₈ : S₉, throw both of these wedges. (instruction)

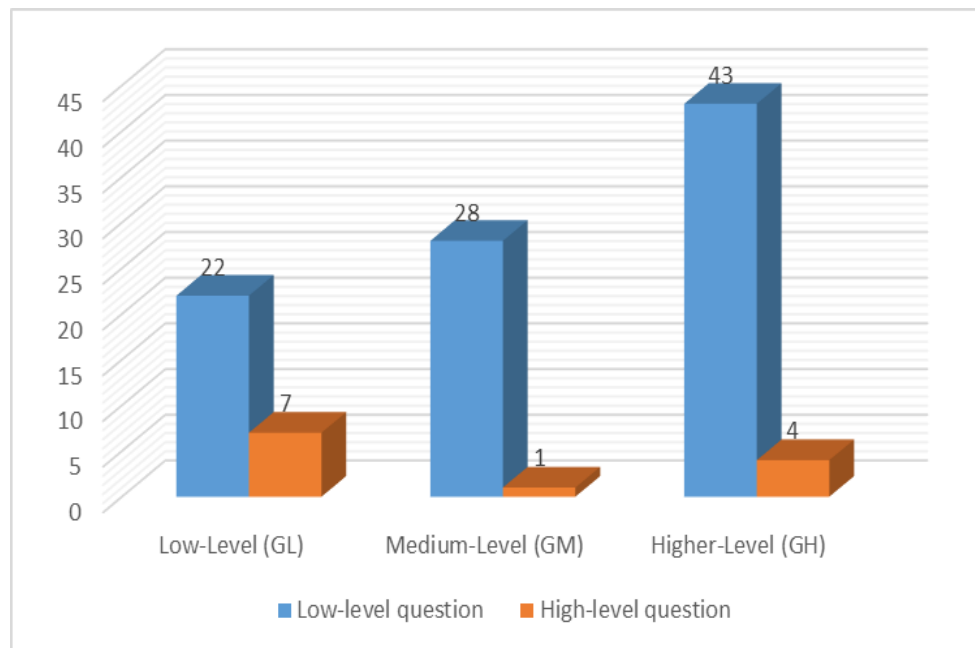
S₉ : This is a bit heavy. Can we move it? Would it form an inclined plane? (asking for confirmation)

S₁₀ : Yes, it would. (confirmation)

S₉ : We can do it side-by-side like this. (proposing an idea)

S₁₀ : Okay, now it is better.

The total number of questions related to the level of student-student questions theme in the GH, GM and GL groups is given in Graph 2 below.



Graph 2. Results of the groups related to the level of student-student questions theme

It can be suggested that questions asked by the teacher were formed in order to support students' ideas, ensure thinking responsibility between students, encourage students to speak their mind and help students understand the topic on a deeper level or make associations in small group discussion (Chin, 2006). Questions asked by the teacher constitutes an important dimension of the in-class dialog. Within the scope of this study, however, only questions asked by students were evaluated.

Student questions were coded as higher-level and lower-level questions. It was found that students in each group asked lower-level questions more frequently compared to higher-level questions (see Graph 2). As seen in the graph, the GH was the group that used lower-level questions (e.g.: “Can’t we use it as the formula?”, “Are we supposed to find it in mg?”, “Now, we found its weight to be 560. Isn’t this a separate value?”, “What is Fs? Isn’t it k multiplied by N?”) most frequently. Among the groups in the study, higher-level questions were asked by the GL group most frequently. The dialog consisting of questions asked by the students in the GL group to their peers can be seen in Episode 5. It can be seen from the dialog that the students in the GL group questioned the process and asked higher-level questions such as “What sort of force do we need to apply?” or “It is 40 Newtons. No, it is 4 Newtons. How many Newtons is that?”.

Episode 5 (GL)

- S₁ : Now, we need to apply a small force to this, right? (lower level question)*
- S₂ : What do you mean we need to apply a small force? (higher-level question)*
- S₁ : Now, it does not move it, right? (lower-level question)*
- S₁ : It is 40 Newtons. No, it is 4 Newtons. How many Newtons is that? (higher-level question)*
- S₂ : Now, it does not move when we apply a small force.*
- S₃ : Okay, I got that part.*
- S₁ : How many Newtons does it take to move it? (lower-level question)*

- S_2 : *It moves with 0.6, it does not move with 0.4.*
 S_1 : *Right, 0.4. What is the F? $F=0.4$ Newtons.*
 S_1 : *Okay, but it needs to stop, S_2 .*
 S_1 : *What is N? (lower-level question)*
 S_2 : *...isn't it the Newton value that we found?*
 S_1 : *Isn't it equal to g? (lower-level question)*

DISCUSSION and CONCLUSION

This study was aimed at investigating the process experienced by students with different success levels during small group discussions in argumentation applications. Among the groups with three different success levels, the GH group was the most active in terms of metacognition and process management, followed by the GM group and the GL group. Since metacognition is described as individuals' thinking about the foundation of their beliefs related to a concept, about evidences that support or do not support a concept, about the status of their perceptions and evaluating consistencies and generalizations within understandings of others (Hennessey, 1993), it can be said that the GH group experienced these situations more frequently and participated in the learning process more actively. Similarly, it was seen in a study conducted by Hand, Wallace and Yang (2004) that students who used the SWH approach were more successful in science subjects compared to those who did not and students gained awareness related to cognitive and metacognitive processes. For this reason, study results are consistent with the above mentioned research. Similarly, in terms of process management, the GH group used statements reflecting instruction, peer teaching, peer support, confirmation, asking for confirmation, making suggestions, proposing alternatives and controlling the understanding, which are essential to form arguments, more frequently compared to other groups. Çinici et. al. (2014) found that students enjoyed working in cooperation with each other in argument formation process, engaging in discussions and receiving peer support and found the use of caricatures in the process to be fun.

In the scientific process skills category, the GM group was more effective compared to other two groups and the GH group was more effective compared to the GL group. Although the importance of scientific process skills and discussions to raise science literate individuals is emphasized in the program (MNE, 2013), it is not necessary for each individual to be science-minded, as noted by Kaya and Kılıç (2008). What is meant to say here is that problem-solving is easier for societies consisting of individuals who understand science-related situations/events in everyday life or be efficient in finding solutions to problems making decisions, presenting evidence and making claims. In the study conducted by Ulu and Bayram (2015) with 7th grade students engaging in an activity named "The Relation Between Voltage and Current" within the scope of the Electricity in Our Lives unit, the authors expected students to determine dependent and independent variables, form hypotheses and design an experiment to test their hypotheses and found that the experimental group had a significantly higher level of conceptual learning compared to the control group. As noted by the researchers and observed in this study, students from all age groups find the opportunity to explore concepts related to the subject and other concepts associated with these concepts when activities are performed as laboratory applications based on ABI. Considering the findings related to the supporting the argumentation process, it was seen that the GH group and the GM group used statements supporting the argumentation process more frequently compared to the GL group. The GM group used such statements most frequently. If we consider the study conducted by Ulu and Bayram (2015) once again, one of the reasons behind the difference between the experimental group and the control group in terms of conceptual learning was found to be activities performed by experimental group students at

the “Claims” and the “Evidences” stage of the student-oriented dimension of the ABI approach. Since the SWH approach involves processes such as turning evidences into claims and establishing relations between evidences and claims, it contributes to the improvement of conceptual learning of students (Akkuş, Günel ve Hand, 2007).

Considering student questions in small group discussions, it was seen that students frequently used lower-level and middle-level questions, whereas they did not use higher-level questions. GH was the group that used low-level questions most frequently. In terms of higher-level questions, the students in the GL group asked higher-level questions most frequently. We believe that the reason behind this result is that one of the students was more active compared to other two students in this group. Questioning is essential for an efficient argumentation (Chin & Osborne, 2010). It is very important for the process that students form questions among themselves and express these questions, make inquiries. However, these questions must be quality questions that require inquiry. Students’ asking questions constantly does not mean they learned or will learn better (Aguiar, Mortimer, & Scott, 2010). In addition to student questions, teacher questions were examined in the study conducted by Günel, Kingır and Geban (2012) and it was found that students were as active as teachers in the classroom. In terms of the relation between discussion and the level of questions asked, it was found that the more high-level questions and follow-up questions asked by the teacher, the more discussions occurred. The role of the teacher in the process may be evaluated by examining teacher questions in other studies as well.

Generally, it was found that students with all success levels were physically and mentally active during small group discussions. It was found in the study conducted by Akkuş et al. (2007) by taking different success levels into account that SWH applications were effective on success levels of students. Researchers (Duschl, 2008; Kaya & Kılıç, 2008; Khun, 2010) who consider discussion to be central for science note that teaching students how to engage in discussions with in-class activities can lead to meaningful learning of science concepts. It was found in our study as well that the argumentation process was effective in all success levels and the process contributed to students in terms of reasoning, thinking like a scientist and understanding the scientific process. Students’ thinking about and questioning a problem, designing activities, discussing what they learned through these activities with their peers and reflecting on the results in research-inquiry based approaches allow students to gain properties that a science literate individual should have (Demirbağ, 2011). In the study conducted by Hand et al. (2004), it was found that when inquiry based teaching applications were used together with the SWH approach and higher-level cognitive questions were added to the standard experiment structure, students in the SWH group showed a significantly better performance compared to students in the traditional teaching group. Similar studies in the literature show that the SWH approach has positive effects on conceptual understanding as well (Akkuş, Günel & Hand, 2007; Keys, Hand, Prain & Collins, 1999; Kingır, Geban & Günel, 2012). In this respect, the results of previous studies seem to support our study.

Future studies may investigate the effect of the age factor by conducting studies not only with university students, but also with primary school and middle school. Therefore, experiences of groups with different success levels during small group discussions in argumentation applications were examined using the force and its effects subject. Similar studies may be conducted with different science subjects and their results may be evaluated. Also, studies in which not only scientific issues, but also socio-scientific issues are addressed may be conducted. Since the field knowledge and pedagogical knowledge of teachers are important in argumentation applications, it is recommended that in-service training programs or collaborative projects with universities are held to improve teachers’ knowledge.

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Critical Inquiry Based Learning: A Model of Learning to Promote Critical Thinking Among Prospective Teachers of Physics

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ABSTRACT

Teaching critical thinking (CT) to prospective teachers has been a concern for a long time, and prospective teacher training becomes an appropriate period for interventions that promote CT ability. Therefore, it is necessary to develop a model of learning that accommodates aspects of prior knowledge, motivation, and CT. This study aims to develop *Critical-Inquiry-Based-Learning* (CIBL) model to promote the CT ability of prospective teachers of physics (PTP). This study is based on Nieveen's theory about the criteria of rich product quality (valid, practice, and effective) and the theory of Borg and Gall about development research. The CIBL model embraced three criteria, namely validity, practicality, and effectiveness. The CIBL model was validated by experts through the mechanism of the focus group discussion (FGD) (for validity aspect), the implementation of the model in the class were observed by a number of observers (for practicality aspect), and the assessment of CT ability is done after the learning process (for effectiveness aspects) and then analyzed. The findings of the research showed that the CIBL model is feasible because of its validity, practicality, and effectiveness. This means that the CIBL model was able to promote CT ability of PTP.

Keywords: CIBL model, critical thinking ability.

INTRODUCTION

Critical thinking is one of the essential skills that must learner possess in the 21st century (Partnership for 21st century, 2011), and it is one of the goals of science education (Bailin, 2002). The development of critical thinking skills is often listed as the most important reason for formal education because the ability to think critically is essential for success in the contemporary world where the rate at which new knowledge is created is rapidly accelerating (Marin & Halpern, 2011). Wasis (2016) explain that CT as one of the higher order thinking skills, supposed to be center of learning development, because it made people have life skills, creativity, and innovation so that can finish various real-life problems which are more complex in 21st century.

Teaching CT to the prospective teacher has garnered attention for a while, and the role of future teachers seems more crucial than ever before for educational systems in terms of seeking improvement in critical thinking (Sendag et al., 2015). Ashton (1988) stated that



teacher educators have to teach and give cognitive skills to prospective teacher before they train them to students in the classroom. Warburton (2008) proposed that education before becoming a teacher is proper time to intervention activities which promote their critical thinking. Therefore, school or educational institution has to improve critical thinking ability to the prospective teachers (Innabi & Elsheikh, 2007).

CT is reasonable and reflective thinking focused on deciding what to believe or do (Ennis, 1996), its detailed description of some characteristic including the process of interpretation, analysis, evaluation, inference, explanation, and self-regulation (Facione, 2011). CT is one of the higher-order thinking skills element, that can be taught (Woolfolk, 2009). The educators believe that improving learner's critical thinking is very important (Albrecht & Sack, 2000), however few of them have an idea how to teach it (Duron et al., 2006). Although one of the goals of university education is to improve students' critical thinking, courses are generally taught by the lecturing method and the content presents little chance for students to discuss topics so as to enhance their critical thinking (Demirhan, Önder & Beşoluk, 2014). Teaching critical thinking requires holistic approach and should involve a set of appropriate learning models oriented on purpose that can make learner manipulated their cognitive skills (Thompson, 2011).

Several previous studies (e.g., Fine & Desmond, 2015; Hamlin & Wisneski, 2012; Wasis, 2016) recommend inquiry activity as teaching foundation to promote 21st century needs, including critical thinking. Through inquiry activities, students construct their knowledge actively so that desired learning outcomes can be achieved (Samarapungavan et al., 2008). Inquiry process cannot be separated from critical thinking (Sriarunrasmee et al., 2015), inquiry have an effect toward on students' critical-thinking skills in science courses (Duran & Dökme, 2016). Inquiry-based learning activities also can improve student's critical thinking skills (Thaiposri & Wannapiroon, 2015). Learning occurs when learners have direct experience on learning activities that they are doing (Sriarunrasmee et al., 2015). When learner train to investigate, it could help them to develop their critical thinking ability and scientific reasoning (Barrow, 2006). Through investigating and discovering process, learner will collaborate to create new knowledge and will learn how to think critically and creatively, and also how to make discovery through investigation, reflection, exploration, experiment, and "trial and error" (Alberta Education, 2010).

Friesen and Scott (2013) reviewed literature about inquiry-based learning and identified inquiry learning with several learning approaches, where investigating and discovering activities are the basic of learning activity, such as; Authentic Intellectual Work (Newmann et al., 2001), Discipline-based Inquiry (Galileo Educational Network Association, 2008), Problem-based Learning (Barrow, 2006), Design-based Learning (Hmelo et al., 2000), Challenge-based Learning (Johnson & Adams, 2011), and Project-based Learning (Thomas, 2000; Sumarni et al., 2013). Along with the time, inquiry learning has been expanded and modified with integrated it into computerized system as simulation form (virtual laboratory) (Sriarunrasmee et al., 2015; Thaiposri & Wannapiroon, 2015). However, virtual laboratory cannot face learner on real situation and environment, because the inquiry basically is conduction between learned topics and real context (Hofstein et al., 2001), so that virtual laboratory cannot replace real laboratory (Cassady et al., 2008).

Focusing on implementation of inquiry, based on a study conducted by Verawati (2013) there are several problems on conducting inquiry for the purpose to improve CT skills of prospective teachers, one of them has difficulty to conduct inquiry directly without the prior knowledge about the concept that will be taught with inquiry. This is in accordance with the previous findings that learners experience problems with relating new content with prior knowledge (Blumenfield et al., 1991; Gulbahar & Tinmaz, 2006; Marx et al., 1997; Lee & Tsai, 2004). Prior knowledge is one of the most influential factors in learning because it is

processed by what learner has known, believe, and done (Ambrose & Lovett, 2014). When prior knowledge is accurate, enough, active, and correct, learners can construct their knowledge on that foundation, relating new knowledge with prior knowledge which is possible for them to learn, take, and use it when they need it (Ambrose et al., 2010). When prior knowledge is wrong (for example the ideas, models, theories, or facts are inaccurate), learner tend to be restricted because they may ignore or decline new evidence and information which inappropriate with their prior knowledge (Dunbar et al., 2007; Chinn & Malhotra, 2002).

There is a fact that before the implementation of inquiry, students have prior knowledge about the concept of teaching material, so generally in learning process there will be a conflict between their prior knowledge and inquiry process itself called conflict cognitive because there are conception changes in learner (Limon, 2001). Conflict cognitive has a big role in conceptual changes (Lee, 1998), but this does not always consistently cause conceptual changes (Vosniadou & Ioannides, 1998), which means although learners are faced with new contradictive information in learning, they often do not recognize the conflict. Piaget also stated that several learners have not adapted response in learning task where learners are unaware of any conflict (Lee et al., 2003; Limon, 2001). Therefore, some things can be done to facilitate learners in recognizing conflict and to bring up student's interest to learn, like presenting contradictive information or anomalous data (Chinn & Malhotra, 2002; Thagard, 1992). According to Limon & Carretero (1997) presenting contradictive information or anomalous data on the other hand helps learners to reflect more about their ideas to bring explanation of learned phenomena, and may be able to activate their curiosity of learned phenomena. In critical thinking study, giving explanation based on learned ideas or phenomena is one of the studies and become main indicator of critical thinking (Facione, 2011; Paul & Elder, 2006; Fisher, 2003). Which means by presenting contradictive information or anomalous data in learning, it can train critical thinking ability to learners indirectly.

Furthermore, so that the information at the beginning is more meaningful, it is used advance organizer. Advance organizer is one of the form of cognitive thinking stimulation in learning which can support learning motivation (Dolezal et al., 2003). Advance organizer is information presentation that bridging new learning materials with related ideas (Shah, 2004; Zaman, 1996). Advance organizer can be used by learners to organize and interpretation information which can be used by them for next learning (Shafdar et al., 2014; Mayer, 2003). On the other side, advance organizer encourages the usage of critical thinking skills, like analyzing abstract concept besides making understanding deeper and expanding the relations of ideas (Kwaku et al., 2014).

This study aims to develop a specific learning model for promoting the critical thinking ability of prospective teachers of physic. Model development is based on inquiry processes in learning, and accommodates aspects of prior knowledge, motivation, and critical thinking in learning. Then the learning model in question is the Critical Inquiry Based Learning (CIBL) model. The learning steps in the CIBL model are orientation, exploration, analysis, inference, evaluation, and reflection. The results of model development and implementation in the class are described in this article.

METHODS

This research is a development research that will produce a product which is CIBL model. The research that based on Nieveen's theory about the criteria of rich product quality (valid, practice, and effective) (Nieveen, 1999) and the theory of Borg and Gall (1983) about development research. CIBL model embraced three criteria, namely the validity, practicality, and effectiveness. The plot of development of CIBL learning model is explained at Figure 1.

Pre-development of the model was done by conducting a preliminary study of model development needs, planning of model development, and develop preliminary form of product (composing a CIBL model hypothetical framework).

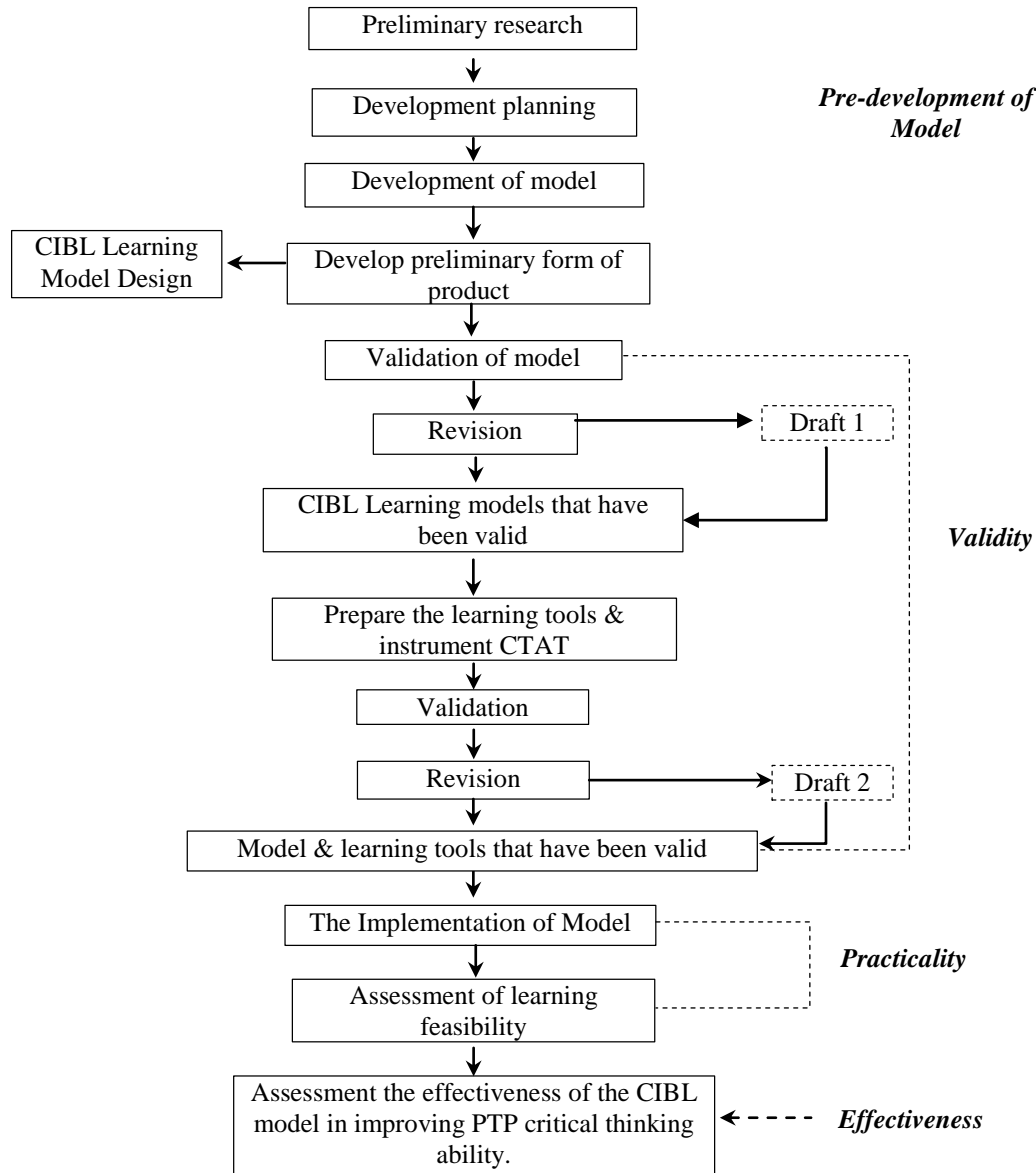


Figure 1. The plot of development of CIBL model

Validity of CIBL Model

The hypothetical framework of the CIBL model that has been arranged is further validated. The validation has been done with containing two elements of validity, which are content validity and construct validity. Content validity is all components that form the model should be based on state-of-the-art knowledge, and construct validity is all components should be consistently linked to each other (Nieveen, 1999). The CIBL model was validated by the experts. Technically validating CIBL model was done with Focus Group Discussion (FGD) mechanism. FGD is followed by researcher, and four experts as validator. Suggestions and feedback from validators would be followed-up to fixed CIBL model. After the CIBL

model were declared valid, then compiled learning tools and instrument of critical thinking ability test (CTAT) as a supported model. Learning tools include lesson plans, learning module, and worksheets. Learning tools and instrument of CTAT are further validated by two validators. Suggestions from the validators are further followed up for the improvement of learning tools and instruments. Learning tools are operationalization of CIBL model when implemented in the classroom.

Validity assessment of CIBL model, learning tools, and instrument of CTAT using the validation sheet base on Likert scales consist of five scoring scale for each item of declarations, there are 5 = very valid, 4 = valid, 3 = quite valid, 2 = less valid, 1 = invalid. Obtained score from the validators are converted into five-scale qualitative data (Bahtiar & Prayogi, 2012) as shown in Table 1.

Table 1. *The validity criteria of CIBL model, learning tools, and the instrument of CTAT*

Interval (Va = validity level)	Criteria
$Va > 4,21$	Very valid
$3,40 < Va \leq 4,21$	Valid
$2,60 < Va \leq 3,40$	Quite valid
$1,79 < Va \leq 2,60$	Less valid
$Va \leq 1,79$	Invalid

Learning model, learning tools, and instrument of CTAT have good validity degree if the minimum of validity degree is valid. If the validity degree is less than valid, they have to be revised. The reliability is counted with the equation of percentage of agreement by Emmer and Millet (in Borich, 1994), they are reliable if the *Percentage of Agreement (PA)* is $\geq 75\%$.

Practicality of CIBL model

The practicality of the CIBL model is evaluated upon being implemented in the classroom. The practicality of the model will be evaluated from the learning feasibility (LF) using the learning tools as supported of CIBL model. It was observed by two observers by means of providing a score from 1 to 5 using the observation sheet. Observers are also asked to give advice (if any) toward the implementation of the model. The scores given are then analyzed to determine the average scores. From the average scores, their category can be established, as presented in Table 2. CIBL model is practice when the minimum category of LF are good criteria. The subjects of model implementation are 17 of prospective teachers of physic (PTP) in Institute Teacher Training and Education Mataram, West Nusa Tenggara Province, Indonesia. The number of meetings of learning at the implementation of the model as much as four meetings on the subject matter of fluid mechanics.

Table 2. *The assessment category of learning feasibility using CIBL model*

Interval	Criteria
$LF > 4,21$	Very good
$3,40 < LF \leq 4,21$	Good
$2,60 < LF \leq 3,40$	Adequate
$1,79 < LF \leq 2,60$	Less
$LF \leq 1,79$	Poor

Effectiveness of CIBL model

The effectiveness of the model was evaluated from the improvement CT ability after the implementation of the model using the instrument of CTAT. CT ability are evaluated using the scoring technique adapted from *Ennis-Weir Critical Thinking Essay Test*, where the highest score is +3 and the lowest score is -1. The indicators of CT ability in this study are

analysis, inference, evaluation, and decision making. While to know the score change of CT ability, its analyzed using *n-gain* equation (Hake, 1999). The conversion of critical thinking score (CTs) refers to Table 3.

Table 3. *The score criteria of CT ability*

CTs Interval	Criteria
$X > 8,8$	Very critical
$5,6 < X \leq 8,8$	Critical
$3,6 < X \leq 5,6$	Critical enough
$0,8 < X \leq 3,6$	Less critical
$X \leq 0,8$	Not critical

FINDINGS

The hypothetical framework of CIBL model were arranged as a preliminary form of model, it is based on the empirical and theoretical study supported the model which are accommodates inquiry process, aspects of prior knowledge, motivation, and critical thinking in learning. Syntax of the CIBL model consist of orientation, exploration, analysis, inference, evaluation, and reflection. Learning steps of CIBL Model are explained in Table 4.

Table 4. *Learning steps of CIBL Model*

Syntax of CIBL	Learner behavior
1. <i>Orientation</i>	<ul style="list-style-type: none"> • Establishing set and giving learning objectives. • Presenting or demonstrating contradictory information (anomalous data) to generate student's motivation in learning. • Presenting advance organizer as the follow-up of the presented anomalous data.
2. <i>Exploration</i>	<ul style="list-style-type: none"> • Guiding students to experiment/investigate. • Guiding students to propose problem formulation and hypothesis based on objectives of experiment, identify variables in experimental activities, and define operational of variables. • Guiding students to plan experimental procedure.
3. <i>Analysis</i>	<ul style="list-style-type: none"> • Guiding students to analyze the data of experiment result to test the proposed hypothesis by reviewing various reference sources.
4. <i>Inference</i>	<ul style="list-style-type: none"> • Asking students to make inference based on data analyzing of experiment result.
5. <i>Evaluation</i>	<ul style="list-style-type: none"> • Asking students to make evaluation about experiment which is done.
6. <i>Reflection</i>	<ul style="list-style-type: none"> • Asking student to do advanced investigation by presenting the problem of anomalous data which is related with the experiment.

The hypothetical framework of the CIBL model that has been arranged was further validated. The results of the validator assessment of the CIBL Model are shown in Table 5.

Table 5. *The experts validation results on the CIBL Model*

Aspects of validation	Average score	Category
Content validity	<ul style="list-style-type: none"> • The need for development of model. 4.25 • The model designed base on state-of-the-art of knowledge. 4.21 	Very valid
Construct validity	<ul style="list-style-type: none"> • Consistency and logically of all arrangement components of model. 4.13 	Valid
<i>Va</i>	4.20	Valid
<i>PA (Percentage of Agreement)</i>	90.1%	Reliabel, $PA \geq 75\%$

The validity results show that CIBL learning model which is developed was declared valid ($V_a = 4.20$). The validation of learning tools and instrument of CTAT that compailed the CIBL model was done, the average score of validation of both consist of 4.24 (very valid criteria) and 3.94 (valid criteria).

In the implementation step, the practicality of the CIBL model was evaluated from the learning feasibility (LF) using the learning tools as supported of CIBL model. It was observed by two observers, and observation result of LF using CIBL model were done very good ($LF = 4.75$).

The effectiveness of the model was evaluated from the improvement CT ability after the implementation of the model using the instrument of CTAT. The results of CT ability of prospective teachers of physic (PTP) shown in Table 6.

Table 6. *The results of CT ability of PTP*

CTs interval	Criteria	Pre test			Post test			N-gain	N-gain criteria
		Mean	F	%	Mean	F	%		
$X > 8,8$	Very critical	-1.53	0	0	72.34	12	70.59	0.76	High
$5,6 < X \leq 8,8$	Critical		0	0		3	17.65		
$3,6 < X \leq 5,6$	Critical enough		0	0		1	5.88		
$0,8 < X \leq 3,6$	Less critical		2	11.76		1	5.88		
$X \leq 0,8$	Not critical		15	88.24		0	0		
Amount			17	100		17	100		

DISCUSSION and CONCLUSION

Syntax of the CIBL model consist of six phases of learning, that are *orientation*, *exploration*, *analysis*, *inference*, *evaluation*, and *reflection*. In the orientation phase learners are confronted with contradictive information (anomalous data) to generate their motivation in learning as well as to explore the prior knowledge of learners, and advance organizer conducted as the follow-up of the anomalous data presented as well as the bridging of prior knowledge for further exploration. Ausubel (in Arends, 2012) argued that the educator has to find ways to anchor the new learning materials to the learners' prior knowledge and ready the students' minds so that they can receive new information. Presenting the contradictive information or anomalous data is seen as a solution that can attract interest and ensure that prior knowledge emerges (Ambrose & Lovett, 2014; Chinn & Malhotra, 2002; Chinn & Brewer, 1998). After the learner were confronted with an information, fact or problem, the teacher encourages them to create and prove the hypothesis, and think of the means used to test the hypothesis through exploration (experiment) (Suchman, 1962). Construction of knowledge is done by formulating a new hypothesis and testing it through the exploration (Fine & Desmond, 2015). Guiding learner to analyze the data of experiment result to test the proposed hypothesis by reviewing various reference sources were conducting in this model. Conducting further analysis, compiling and communicating the results of data processing in the experiment are critical thinking activity (Sarwi et al., 2012). After the analysis, learner make inference based on data analyzing of experiment result. Involving inference processes in learning strategies leads to better learners' critical thinking skills (Miri, et al., 2007). The evaluation process becomes part of a very important learning phase after inference. Aside from being an indicator of critical thinking, according to Yenice (2011) evaluation is also a correct step in problem solving. Reflection into the last phase of the CIBL model. In this activity learner do advanced investigation by presenting the problem of anomalous data which is related with the experiment.

The validity results show that CIBL learning model which is developed was declared valid. The validity level (V_a) of CIBL model is 4.20 (its valid if; $3.40 < V_a < 4.20$) with the percentage of reliability is 90.1% (reliable). The recommendation from validators in FGD is

that CIBL model is valid with some revision. The content validity in this study has two main components as the basic development of CIBL model, which are needs and state-of-the-art knowledge.

Strengthening in need aspects is very important because it is the main basis of the development of a model, also if there is need aspect that cause the model has to be developed. Need aspects of the CIBL model development got an average validity score 4.25 from four validators with very valid criteria. Besides need aspects, state-of-the-art knowledge aspect become very important of content validity to measure as a basic development of model. Strengthening in state-of-the-art of knowledge aspect as a support of development of a model got an average validity score 4.21 with very valid criteria.

Construct validity as an aspect of CIBL-model development is focused on theoretical and empirical review that support the model (Arends, 2012). The syntax of the CIBL model as validation material that model phase shows logical, related, and mutual order of learning activity. The score of this aspect is 4.13 from four validators with valid criteria.

The average score of validation of learning tools is 4.24 with very valid criteria and the percentage of reliability is 90.2% (reliable). Then, the instrument of CTAT in this study is developed to assessing student's prospective teachers of physics CT ability. The average validity result of instrument is 4.75 for each component of content validity and 3.13 for language and question-writing aspect. The final validity result of the instrument is 3.94 with valid criteria, while the reliability of the instrument is 79.37% with reliable criteria. Norris (1989) argued that the facts about the uniqueness level of CT is not finished yet because of many theories in different view, so making measurement and assessment of CT is difficult. Assessing CT distractor with another subject, because transferring to other context may be different with uniqueness of knowledge in CT. In this study, researcher made simplification with developing the instrument of CT test based on 4 critical thinking indicators according to Ennis (1991) that similar to critical thinking indicators of experts and previous researchers, such as; a) analysis (Facione, 2011; Fisher, 2003), b) inference (Facione, 2011; Fisher, 2003; Scriven & Paul, 2009; Paul & Elder, 2006), c) evaluation (Facione, 2011; Scriven & Paul, 2009); Paul & Elder, 2006; Reid, 2006), and d) decision making (Rudinow & Barry, 2008; Fisher, 2003; Stenberg, 1986).

In the implementation step, the practicality of the model was measured from LF. Observation result of LF using CIBL model were done very good ($LF = 4.75$). Its cause of the supports, especially the availability of the learning tools, including handbook (module) and worksheet. When learning tools are designed well, it can give information which help learner more effective to accomplish learning objectives (Parkes & Harris, 2002). Learning tools that are good designed are functioned as communication tool, tool of learning plan, learning plan for students, learning resources, and tool for learning evaluation (Fink, 2012). The support from module is also very important in this study. The material in the book is arranged systematically so it can condition students to learn (Levin, 2008). The worksheet in this study is designed as the guidelines of LF in inquiry activity according to CIBL model to train student's CT ability. According to Sriarunasmee et al (2015) scientific process skill is able to be tools that can develop thinking skills including critical thinking skill, efficient LF, and correct problem solving. Scientific process skill has a great effect in learning because it helps learner to improve higher mental skill, such as critical thinking, decision making, and problem solving (Lee et al., 2002; Koray et al., 2007).

The assessment result on CT ability of PTP showed that average score of CT of 17 PTP in the pretest was -1.53 with not critical criteria (not critical, if $X \leq 0.8$). The assessment of CT ability after the implementation of CIBL model (posttest) showed that average score of 17 SPTP was 8.76 with critical criteria (critical, if $5.6 < X \leq 8.8$), also the N-gain was 0.76 with high criteria (results are shown in Table 6). The study results showed that CT ability tend to

increase from not critical to critical criteria, so it can be state that CIBL model development is effective to promote CT ability. This result is also inseparable from the validity of CIBL model that aims to promote CT ability. CIBL model has accommodated several recommendations in learning which is the main idea in developing CIBL model, such as training CT by presenting contextual or real-life case in learning, motivating to openly discuss, and encouraging experimental activity oriented by inquiry (Miri et al., 2007; Fine & Desmond, 2015; Samarapungavan et al., 2008). CIBL model based on inquiry activity was integrated with worksheet oriented scientific process skill. According to Sriarunrasmee et.al (2015), scientific process skill can be instrument that can improve critical thinking.

Learning feasibility (LF) has become effectiveness factor of CIBL model. Learning steps (syntax) in CIBL model, that are orientation, exploration, analysis, inference, evaluation, and reflection are designed consistently to train intact PTP critical thinking throughout the learning process. Theoretical and empirical review showed that CT can be taught and trained (Woolfolk, 2009), persistently (Fisher, 2003), and continuously (Miri et al., 2007; Qing et al., 2010). Learning activity based on inquiry can improve critical thinking skills (Thaiposri & Wannapiroon, 2015). Learning orientation was done by facing learner with contradictive information (anomalous data) and then by presenting advance organizer. Presenting contradictive information or anomalous data is viewed as a solution that can attract interest, ensuring the prior knowledge emerges (Ambrose & Lovett, 2014; Chinn & Malhotra, 2002; Chinn & Brewer, 1998), and helping learners to reflect their ideas to give explanation about learned phenomena (Limon & Carretero, 1997). Giving explanation based on ideas or phenomena is one of the study and become main indicator of critical thinking (Facione, 2011; Paul & Elder, 2006; Fisher, 2003).

Exploration is the second phase in CIBL model after the orientation phase. When learners train to investigate, it will help them to improve their critical thinking and scientific reasoning (Barrow, 2006). Through investigating and discovering process, learner will collaborate to create new knowledge and learn to think critically (Alberta Education, 2010). Teaching strategy to develop higher order thinking skill include critical thinking can use inquiry-oriented experiment (Miri et.al, 2007). After exploration phase, then learner do analyze, inference, and evaluate. Analysis, inference, and evaluation processes are main indicators of critical thinking. Those indicators were adopted into syntax or phases of CIBL model. This is appropriate given researchers' previous recommendations or findings that several indicators of CT (analysis, inference, and evaluation) are in low category (Prayogi, 2013; Qing et al., 2010; Miri et al., 2007). According to Miri et al (2007), integrating CT indicators into learning can train them more in CT.

The result of this study is also supported by valid learning tools of CIBL model, such as lesson plans, learning module, and worksheets, that help learner to train their critical thinking ability. The learning tools is supporting factor which help the students to organize CIBL model that used in learning, so that they can train their CT ability. Constructivism learning theory of Vygotsky said that well-organized learning produces mental development (Woolfolk, 2009). Critical thinking is mental processes (Sternberg, 1986; Dwijananti & Yuliyanti, 2010). The strong designed learning tools can give information that help learners are more effective to achieve learning objectives (Parkes & Harris, 2002). The learning module also supported the improvement of learners CT ability. Module is equipped with attributions to achieve critical thinking objectives. The module as a part of learning tools contains information, tools, and text that are required by teacher in presenting materials and skills that have to be learned by students, those skills are critical thinking in this context.

The test of CT ability showed that the N-gain score is 0.76 (high criteria), but there are five of PTP with medium N-gain score (the range score, 0.30–0.70), and one of five of PTP is less critical at the posttest. These results are affected by motivation of the PTP in learning.

When the contradictory information is presented in the beginning of the learning, there are several PTP that shows less attention and do not give responses, even though this learning activities mean to motivate PTP in learning besides to think critically. This is shown from observation result of PTP activity in learning. Motivation factors toward content and context learning material are very important in learning (Pintrich, 1999; Pintrich et al., 1993). According to Pintrich (1999), interest and motivation factors can affect the process of believe establishment that occur when learners get new knowledge or are faced on new situation in learning even when they are presented with new information that is contradictory with their prior conception. Someone's motivation to engage in cognitive activity can determine impact of delivered information (Cacioppo & Petty, 1982; Cacioppo et al., 1996). High motivation in learning showed high level of cognitive necessity, this become learner's predictor to engage in the intellectual challenging activity (Steinhart & Wyer, 2009), which is critical thinking. Students with high cognitive activity and motivation will be better in elaborating information, showing performance which are better in cognitive assignments, and more effective on complex problem solving (Luong et al., 2017).

Generally, the results of this study show that the CIBL model has been declared valid, practice, and effective to promote critical thinking ability of prospective teachers of physic, including aspects of analysis, inference, evaluation and decision making. The results of this study has become the important findings that the CIBL model can promote critical thinking ability of prospective teachers of physic, so that can be used as a reference and consideration of educators or prospective teachers' instructors in learning for the purpose of meeting prospective teachers learning needs in the direction of improving their critical thinking ability. However, further research by other researchers is needed to evaluate the impact of learning using the CIBL model to improve the critical thinking disposition which is not revealed in this article.

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Analysis of the forms of argumentation of teachers in training in the context of a socio-scientific issue

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ABSTRACT

The aim of this study is to analyze the forms of argumentation regarding a socio-economic question related to the consumption of coffee by a group of 32 students with a Bachelor's Degree in Natural Science and Environmental Education. For this, a rubric was used to analyze three fundamental aspects: content, structure, and position or response in the face of the arguments. The results indicate that the students can produce arguments with content, but difficulties are observed in regard to their developing arguments with structure. Furthermore, the students tend to avoid debate situations, which does not allow for the improvement of their arguments. Despite that, the participants acknowledge the importance of including argumentation in their training, and they are aware of their difficulties. This indicates the need to promote a greater number of studies that would allow the importance of argumentation to be included in the educational processes.

Keywords: Argumentation in the sciences, forms of argumentation, teacher training.

INTRODUCTION

Since ancient times, when philosophers began looking for the reason for things, argumentation achieved a fundamental position in the construction of knowledge and of public debate. At the time, logic and rhetoric were the fields that showed an interest in argumentation (Bochenski, 1966; Aristóteles, 2000). Logic kept its central importance throughout the whole of the Middle Ages (Beuchot, 1987) and even up until the beginning of the modern age, when it was eventually relocated along with other elements that were condensed into what has since then been called method or methodology, that is to say, the rules of scientific work (Cristancho, 2013).

This also caused logic to establish new ways of working and researching beyond argumentation as such (Garrido, 1991; Russell, 2013; Wittgenstein, 2012). In any case, argumentation continues to be an important component in the construction of knowledge. It is introduced in all professional degrees, and it has special relevance in training for the natural and applied sciences, as well as for the social sciences and humanities; not only to improve



research skills and establish the appropriate perception of these types of sciences, but to also give meaning to the academic development of the students (Mcneill, González, Katsh & Loper, 2017; Evagorou & Osborne, 2013; Gültepe & Kiliç, 2013). At the same time, it has been proven that there is a positive relation between the knowledge of content of the people who use arguments and the number of arguments they produce during a scientific argumentation (Hakyolu & Ogan-Bekiroglu, 2016; Aktamiş, Hiçde & Özden, 2016).

With regard to this, research such as that carried out by Jiménez-Aleixandre (2010), Osborne (2010); Berland, and Lee (2012), indicate that scientific argumentation is a dynamic social process, where ideas are tested, given that those involved work to improve their approaches and persuade other people's ideas, making use of new data, evidence, and proofs.

In their research, it is suggested that argumentation does not arise naturally in most people and depends upon environments and practices (Osborne, Erduran and Simon, 2004; Evagorou & Osborne, 2013; Mcneill, González, Katsh and Loper, 2017). With regard to this, much of the research on reasoning has focused on the available evidence; for example, studying how data is used in the argumentation process (Hogan & Maglienti, 2001; Kolstø, 2001; Sandoval & Millwood, 2007; Nielsen, 2012; Zeidler, Herman, Ruzek, Linder and Lin, 2013).

Studies undertaken by Asterhan and Schwarz (2007), Kuhn (2010), Berland and Lee (2012), show that favoring the argumentation process in the classroom contributes to the building of solid points of view. For instance, debating in class improves the structure of arguments, the understanding of content, and helps to improve the learning of that knowledge. For example, Duschl (2008), Jiménez Aleixandre and Erduran (2008); Berland and Lee (2012); Evagorou and Osborne (2013); Namdar and Shen (2016) point out the importance of including argumentation in the pedagogic processes, because it is an opportunity to have access to scientific knowledge and a way of understanding scientific practices.

Other works analyze how environments of debate in the classroom account for the type of discourse the students in a training program are taking on and how they use their knowledge of science and technology in regard to a socio-scientific issue (SSI, from now on). In fact, if argumentation is the exercise of constructing, proposing, and socializing points of view in favor of a thesis or theoretical position, discussion is the process that takes place when diverse arguments come into confrontation. This allows for them to be polished or improved, which is a central component of the training in the social sciences, as a way to help the students make the concepts and theories of a certain discipline their own, and it is also a way for them to get involved in the social construction of scientific knowledge (Erduran and Jiménez Aleixandre, 2008; Chi, 2009; Celik & Kilic, 2014; Namdar and Shen 2016).

The study of the form of arguments and of debating within teacher training environments assists the process of the construction of knowledge in scientific education that allows for future dialog and social processes in the classroom (Plantin and Muñoz 2011; Torres, 2016). It is not possible to expect argumentative processes in students if there are no teachers trained to foster and develop them.

By way of summary, the argumentation processes are used to indicate the mental negotiation processes that can be externalized for the students' debates that defend their ideas about the SSI. This helps decision making and the ability to search for information and act critically (Kolstø, 2001; Nielsen, 2012; Torres and Solbes, 2016; Azar, 2010)

In the framework of these discussions, and taking into consideration that more studies are necessary in order to analyze the perspectives of reasoning of the students in depth, such as finding out what type of information they use when faced with SSI, and what type of tests they use to base their decisions on, this article presents the results of a study that focused on identifying the forms of argumentation that take place in the discussions of small groups when

approaching an SSI. It is related, in this case, with the consumption of coffee by bachelor's degree students of Natural Science and Environmental Education at a Colombian university.

As a point of reference, as well as the previously referenced precedents, works that had forms of argumentation as their object of study were taken into account to carry out this study. The majority of the research has been interested in the quality of the arguments, despite the fact that, as Dawson and Venville (2010) indicate, there is a lack of consensus as to the meaning of assessing the quality of argumentation in research with SSI.

Without a doubt, this is an element that makes it difficult to compare the results obtained in the different investigations. However, the bibliographic revision that was carried out in the development of this document allows us to consider some of the procedures that may help in making an analysis of the arguments in the development of a didactic sequence.

For example, Means and Voss (1996) highlighted that the strength of arguments can be associated with certain criteria, such as the acceptability of the reasons of the argument and its relevance, which is related to the reasons that support the conclusion or affirmation of the argument.

On the other hand, Sampson and Clark (2008) indicated some aspects that allow us to analyze the quality of the students' arguments:

(1) the structure or complexity of the argument (i.e., the components of an argument), (2) the content of an argument (i.e., the accuracy or adequacy of the various components in the argument when evaluated from a scientific perspective), and (3) the nature of the justification (i.e., how ideas or claims are supported or validated within an argument). (p. 449).

Other authors who commented on the same topic are Zohar and Nemet (2002), who analyzed the implementation of a didactic unit to investigate how the use of the knowledge of content affects the construction of arguments and argumentative skills in secondary schools in Israel.

These researchers used different methods to evaluate the quality of the arguments. For example, to analyze written work, they used a rubric that states the following: a) one justification, two justifications; b) structure of the argument when there is no argument, a simple structure supported by a sole justification and two compound structures, the justification of which is supported by one reason that, at the same time, usually explains why the first justification should be accepted.

To analyze oral argumentation, they made a division of recordings of units of analysis that were classified into different categories: explicit conclusions, implicit conclusion, consensus, opposition, and counter opposition. In their conclusions, they affirmed that the instruction of the teacher improves the arguments given by the students in an SSI related to genetics (Zohar & Nemet, 2002).

Similar results were obtained by Venville and Dawson (2010), where they concluded that the group of students that received instructions about argumentation improved the quality of their arguments. These authors indicate that it is important to consider the information and the guarantees as a whole. At the same time, they proposed a scheme that permits us to analyze the complexity and quality of the arguments that range from level 1 to level 4, as follows:

Level 1 refers to assertions or conclusions that do not present a justification; Level 2, arguments that represent assertions or conclusions based on information or guarantees; Level 3, arguments that present assertions based on information and guarantees. They also present the use of guarantees or qualifications. Level 4 refers to arguments that present affirmations or conclusions based on information and guarantees with the use of supporting qualifications.

At the same time, for Penha (2012), the quality of an argument must be based on two foundations: the quality of the arguments used in different ideas or propositions and the quality of the way by which they are opposed. This same author indicates that the quality of the arguments must be related to aspects like the quality of the structure and the quality of the content.

In fact, for Penha (2012), the quality of the structure is associated with the level of complexity of the argument. This could be related to the number of elements of the argument, particularly information, justifications, and counterarguments, whereas the quality of the content of the argument is related to the acceptability and the relevance of the argument.

Even when previous studies do not allow us to infer what is required for the acceptability of the given reasons; it is assumed that they are necessary to support the affirmation of the argument, which may give rise to coherent or incoherent conclusions. In this article, it is considered that the acceptability of the reasons is one of the most important elements in the quality of the arguments. For this reason, if a proportion of the argument uses unacceptable reasons, the conclusions will have no foundations.

Apart from the formal logic aspects, there is another aspect of the quality of the arguments that is linked to the coherence of the structure of its components. The authors mentioned allow us to find some of the main elements, such as conclusions supported by data and justifications that show the relation between data and conclusion.

Therefore, to evaluate the quality of the arguments in the students' forms of argumentation in this study, the following aspects mentioned by Sampson and Clark, (2008); Venville and Dawson, (2010); and Berland and Lee, (2012) were taken into consideration. They imply quality of the argument (content and structure) and quality of opposition among the arguments. The former examines the complexity of the argument based on its acceptability, coherence and adequacy (content of the argument), and the use of information, premises or guarantees (quality of the structure of the argument). The latter refers to the manner of opposing argument-counterargument, refutations. (See *Infra*, Methodological aspects, Table 3).

This study proposes to analyze the forms of argumentation by examining the content and the structure of the arguments, as well as the process of refining, the construction of which is implied in the discussions. Thus, this study was performed considering that the pedagogic practices that include debate and discussion allow students to think and reflect upon aspects, such as the perception of a learned science and the applications of scientific concepts, as well as the link between science and social, ethical, political, and environmental aspects. It is also an opportunity for teachers to generate attitudes and behaviors of participation.

In this sense, the study responds to the following questions: *What are the conceptions of argumentation among a group of student teachers of a Bachelor in Natural Science and Environmental Education degree? What are the kinds of argumentation of a group of student teachers of a Bachelor in Natural Science and Environmental Education degree?*

METHODOLOGICAL ASPECTS

Research method

The research presented in this article was carried out through a diagnosis, followed by an intervention and a reflection (Martínez, 2010; Evagorou and Osborne, 2013). Its objective was to identify the forms of argumentation used by a group of students of a natural science teacher-training program when approaching a SSI related to coffee consumption, from a

laboratory practice experience and the development of a number of activities. It is qualitative research with a case study approach (Yin, 2003). The data obtained were based on written answers of the students to the outlines of the activities and the transcription of lessons recorded in audio.

Sample/study group

The research was carried out in a public Colombian university located in the Department of Boyacá, in the Andean region of Colombia. Thirty-eight (38) students who were sitting for the subject *Experimental Workshop on Natural Science* participated. The students were in the eighth semester of the Bachelor's Degree in Natural Science and Environmental Education during the first semester of 2015. The ages of the participants ranged from 20 to 26 years of age, with 15 males and 23 females.

The development of the didactic sequence took place in workgroups. In this way, 12 groups of 3 to 4 students each were formed, according to the students' interests. For writing this article, the names of the students will remain anonymous. They were given fictitious names starting by the letter of the workgroup they belonged to when they performed the activities. So, for example, all the names of the members of Group A start with the letter A.

The students that took part in the study have already completed 80% of the disciplinary and pedagogic contents of the Bachelor's Degree in Natural Science and Environmental Education program. For this reason, it is presupposed, that they have a good conceptualization of the scientific concepts and possess the necessary requirements to apply what they have learned in the classroom to different everyday situations. So, what is being evaluated is: what the students are capable of doing as regards scientific argumentation processes, how they do it, and what obstacles they find.

Phases of the study

This study was based on the teaching of the SSIs approach which, due to their controversial nature, and for being scientific issues with social implications, they are conducive to debate and promote argumentation (Dawson and Venville 2010; Evagorou and Osborne 2013; Torres and Solbes, 2016). Colombia stands out due to its production and consumption of coffee. For that reason, the topic of the SSI chosen was coffee consumption. This is a controversial topic due to the harmful or beneficial effects of coffee.

On the one hand, coffee is a beverage that is widely consumed worldwide and its popularity is still growing. However, the caffeine present in coffee may cause the stimulation of the central nervous system and an addiction to that substance. Ingesting coffee has also been related to illnesses, such as cancer and arteriosclerosis, despite the phenolic antioxidant components that are supposed to have a protective effect. As there are controversial aspects with regard to health, these elements make the consumption of coffee an SSI of interest to the students.

For the development of this study, various types of activities were developed that involved actions to carry out an initial evaluation, the work sections, and the reflection about the work done. In each of the activities, the answers to the questions formulated in questionnaires were analyzed. The audio recordings produced by the participants were also analyzed. For this, four group activities were programmed, as shown in Table 1:

Table 1. Activities that are part of the research in order to identify the contributions of socio-scientific issues to the development of argumentation. Source: The authors.

N.	ACTIVITIES	AIMS	DURATION
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1.	Introductory guide to scientific argumentation and its importance in the training of science teachers.	To present and discuss different theoretical perspectives with regard to the conceptualization of the argumentation and the SSI.	2 sessions of 120 minutes each.
2.	Development of an experimental guide concerning the extraction of caffeine.	To analyze aspects of the experimental practices and their relation to dialogical processes.	2 sessions of 120 minutes each.
3.	Development of a didactic sequence about the consumption of coffee.	To analyze the types of arguments that the students use to approach an SSI referring to the consumption of coffee.	3 sessions of 120 minutes each.
4.	Reflections about the implementation of the didactic sequence and the argumentation processes in teacher training programs.	To analyze dialogic situations in each one of the groups.	1 session of 90 minutes.

The first one was related to an introduction to scientific argumentation and the SSI. Its objective was that the students discussed different theoretical perspectives and reflected upon the incidence of argumentation in the teaching of the sciences. Some of the questions asked in this session were:

1. What do you understand by argumentation in sciences? What does it include?
2. Do you agree with the ideas expressed in the text? Justify your answer.
3. What conditions are necessary to carry out argumentative processes in the science class?
4. Mention examples of fields of study in which scientific argumentation studies can be carried out. How can this be done? (If it applies, choose a class and base your answer on it).

The second group activity was an experimental practice related to the extraction of caffeine that would allow a discussion about the use of chemical reagents. Given the extension of the guide, some of the questions, some of the questions made to the students in said experimental practice are shown below:

1. What is the role of sodium bicarbonate in the experience?
2. Why is trichloromethane used in the practice?
3. What is the role of anhydrous magnesium sulfate in the experience?
4. Describe the distillation process. The data of boiling temperature coincide with those reported in the literature. Justify your answer. Which is the most volatile component? Which component is collected in the test tube? Which component remains in the distillation flask?

The third group activity was related to the development of a didactic sequence about the consumption of coffee. The description of the activities and the questions posed appear in Table 2 and a fragment of the guide of the didactic sequence appears in Figure 1:

Table 2. Description of the didactic sequence used. Source: the authors.

Aspects of the sequence	Description and intention	Questions of the didactic sequence
HISTORY OF THE DISCOVERY OF COFFEE	In this section, the students are presented with a legend that explains the discovery of coffee and the origin of its use. The students are encouraged to refute or justify the story in the sense that they favor discussion situations. Space is allowed for hypothetical connections with more concrete arguments.	1. Explain how Kaldi's argument could be justified or refuted.
THE CHEMISTRY OF COFFEE	Students are presented with the components of two very common types of coffee here in Colombia (Arabica and Robusta). The students are requested to study the information given and make a decision as regards the type of coffee they should consume arguing why one is better than the other.	2. Based on the data presented, which coffee would you prefer to consume and why?
THE AROMA OF COFFEE	Science is reflected in everyday activities. Information with respect to the characteristic aroma of coffee is presented and the student is asked about different types of coffee. The objective is that the student questions the significance of the different types	3. Why does coffee have that particular aroma? Are instant coffee and whole-bean coffee the same? How are they different?

of aromas in commercial coffee.

THE ACIDITY IN THE COFFEE

The acidity perceived in the coffee infusion has always been recognized as an important attribute of the quality of the coffee. However, in many cases, its importance is ignored in the biological processes. It can also be a tool to articulate concepts of biology and chemistry.

4. Is the acidity in the coffee important? What does it refer to?

The following situation is presented in this section:

COFFEE INDUSTRIALIZATION

The aim of this section is that students question the information that appears on the labels of foodstuffs and electronic devices. They can also analyze its veracity.

5. Mario Pérez wishes to implement thermal treatments in his coffee industry. However, considering the number of technological artifacts that are offered nowadays, he requires the guidance of a professional in science in order to make the best choice. What recommendations would you give Mario?

COFFEE AND HEALTH

In this segment, the students are presented with aspects related to the use of solvents in the industrialization of coffee. Thus, the students can investigate the uses and effects of some products. The students are also given the chance to come to a decision as regards what food industries and the general public should do.

6. Look up information about CH_2Cl_2 , chloroform, and benzene. Explain the effects of the substances mentioned above on human health and the environment.

7 What other substances of domestic use contain methyl chloride?

THE CHEMISTRY OF COFFEE

Coffee contains a number of biochemically active substances; one of the most important and well-known is caffeine, which is a xanthine derivative. In addition, it is a considerable source of polyphenols and phenolic compounds, which may contribute in quantity and variety to the entry of antioxidants. Many chemical compounds have been identified in coffee beans and said compounds react and interact in all the phases of coffee processing in order to produce a final product with great diversity and complexity of structures.¹ In Colombia, there are different varieties of coffee. For example, the Arabica and the Robusta, which are qualitative and quantitatively different in their chemical composition, as shown in the following table:

Componente químico	Arábica %	Robusta %
Polisacáridos	50,8	56,40
Sacarosa	8,00	4,00
Azúcares reductores	0,10	0,40
Proteínas	9,80	9,50
Aminoácidos	0,50	0,80
Cafeína	1,20	2,20
Trigonelina	1,00	0,70
Lípidos	16,20	10,00
Ácidos alifáticos	1,10	1,20
Ácidos clorogénicos	6,90	10,40
Minerales	4,20	4,40
Compuestos aromáticos	trazas	trazas

Source: Quintero (n.d)¹

The antioxidant property of coffee has been proven, which is quite homogenous and potent. The research carried out on these two types of coffee proved that the Robusta type doubles the antioxidant capacity of the Arabica, due to its higher content of chlorogenic acid. Although both are usually mixed to produce coffee with different flavors, the antioxidant capacity of these combinations slightly varies.

2.a. Using the data presented above, which coffee would you prefer to consume and why?

Figure 1: Sub-section of the sequence, which corresponds to the section Coffee and Health

Finally, in the fourth session, a guide that allowed for the analyzing of the dialogic processes of the sequence was developed.

Data Sources and Analysis

For the evaluation of the answers to the questions presented to the students, a qualitative analysis was carried out. From this point of view, with the development of the proposed SSI, the social interactions among the students were taken into consideration. The transcription of the information was carried out from units of analysis from the documents written by the participants and the recordings made around the discussions in the work groups. Each one of the units was analyzed according to its structure and the quality of the argument, in order to make comparisons, to analyze the performance and the participation of the students in each SSI question used, considering the fragments of the chapters of interest.

With regard to this, a content analysis was carried out, taking into consideration the rubric in Table 3. The review of each one of the written answers was corroborated: first, individually by each author, through a guide of answers created by the first author and revised by a professor who specializes in Biochemistry and another one who teaches Didactics of the sciences, with 5 and 8 years of experience, respectively. Afterwards, the answers were jointly corroborated by the authors.

The answers were classified by associations to general concepts that include a broad category that holds some kind of relationship between them. The systematization of the answers to each of the questions was done on the basis of the analysis of the answers given in the questionnaire by students. Afterwards, an interpretation was made of the most common ideas. Also, an effort was made to understand the approach taken by the students toward argumentation in the sciences.

A classification of the answers to determine the kinds of argumentation was carried out according to the rubric shown below, where the following levels, three (3) being the highest and one (1) the lowest, are proposed. The aspects considered in the analysis of the arguments produced by the students (Table 3) are presented in the first column. This rubric was done according to methodologies used by Sampson and Clark (2008); Zohar and Nemet (2002), Venville and Dawson (2010); Penha (2012), and it was previously described in the introduction.

Table 3. Criteria used to analyze the ways of argumentation of the students of the Bachelor's Degree in Natural Science and Environmental Education. Source: The authors.

Aspects of analysis	Description	Level	Description of points
CONTENT OF THE ARGUMENT	The use of data, concepts, affirmations, or guarantees in the arguments. Evaluation of the accuracy of the conceptual references.	3	- Affirmations supported by data and explanatory scientific concepts backed up by sources of information.
		2	- Arguments that contain data and concepts, but some of which are used incorrectly, inaccurately, or incompletely.
		1	- Arguments that present neither information nor explanatory scientific concepts.
STRUCTURE OF THE ARGUMENT	The complexity of the argumentation verifiable by the acceptability, coherence, and competence of the argument.	3	- Arguments that maintain coherence between the information, the justifications, and the conclusions; that is, that the justification is sufficient to validate what wants to be defended.
		2	- Arguments that are coherent but require greater complexity and relevance.
		1	- Arguments that are neither coherent nor sufficient to reach conclusions.
FORMS OF DISCUSSION	Counterarguments, refutations, reaffirmations, or acceptance in response to the arguments of other classmates.	3	- In response to arguments which lack content or are incoherent, proposes opposing ideas and supports them with concepts, data and sources of information.
			- In response to coherent, but incomplete arguments, proposes concepts, data, and sources of information that go deeper and improve the argumentation.
		2	- In response to diverse arguments proposes opposing or complementary ideas, but without supporting them with sources of information or using concepts inaccurately.
		1	- Accepts ideas without questioning them in any way, complementing them, or explaining the argumentation.

ANALYSIS AND RESULTS

According to the four stages presented in the methodological phases, the results are described below.

Results of the application of the introductory guide to scientific argumentation

The guide allowed the evaluation of diverse aspects, such as the conceptualization of the argumentation of the students and their pedagogic and didactic implications in the classroom. The aim of the guide was to show the students different theoretical perspectives regarding the conceptualization of scientific argumentation and its implications for the teaching of scientific concepts, as well as its precedents, and the differences between argument and argumentation. *Conceptualization of scientific argumentation*

Once the reading of the introductory guide to scientific argumentation was finished, some general questions were brought up. They allowed a description of the concept of argumentation given by the students: its implications in the classroom and its effect on the teaching of the sciences. In the following table, the main categories found in the conceptualization of the argumentation are presented. The frequency is expressed by indicating the number of groups that made affirmations in relation to each category.

Table 4. Categories of the conceptualization of the argumentation in the participating groups from their written reports. Source: The authors

Aspects	Categories	Examples	Frequency
Pedagogic and didactic processes	Argumentation and context	The disciplinary, experiential, and didactic components are necessary to argue.	2
	Validation of ideas	It is a thoughtful process that allows for the contrasting of theory with what we think.	5
Epistemological	Relation between argumentation and science	Capacity to explain and support ideas with science.	6
		Science is an argumentative process that is useful to formulate theories.	1

As shown on the Table, the main aspects identified are: a) pedagogic and didactic implications required for the argumentation; b) the relation between science and argumentation, where students point out elements of the epistemology.

It is observed that six groups associate argumentation with the capacity to explain and support ideas, making emphasis on the need to know how a scientific concept arises and develops, and the relation that is established between argumentation and science. This aspect highlights the need to create critical spaces that permit students to justify why they think that way and not in another. An example of this is the intervention of Group E (GE).

GE. "The argumentation is an important aspect of the sciences given that one should have information to theoretically support and prove the arguments. It is mainly based on having knowledge of a topic and being able to explain it. This allows for one's own points of views being taken into consideration and for other people's ideas being respected."

Five groups highlighted that argumentation is a thoughtful process that allows one to contrast ideas and review one's own ideas on theoretical grounds. They emphasized that argumentation requires interpretation, comprehension, and analysis. For example, groups G

and I indicated the need to learn to identify relevant arguments on which to base solid points of view.

In general, the affirmations of the students give relevance to the use of information as a necessary condition for the advancement of scientific knowledge and the validation of the arguments expounded; reaffirming what was said by Sarda and Sanmartín (2000). It is observed that the groups made emphasis on the need to have references to be able to make argumentative processes. This allows for light to be shed on the difference between opinion and argumentation. There were also shown to be categories that value argumentation beyond merely the informative aspect.

The participants indicated that argumentation is a necessary process in the validation of ideas and they acknowledge how argumentation has allowed for the advancement of scientific knowledge and for making reflections in order to contrast one's own opinions with the theoretical fundamentals. Similar aspects were raised by Dimopoulos and Koulaidis (2003), Oliveras, Marquez and Sanmarti (2013), who stated that argumentation permits scientific and general literacy by linking social aspects to the study of scientific concepts.

On the conditions that promote argumentation in the classroom

The students were directly asked about the conditions that are required to promote the argumentation processes in the classroom. They highlighted aspects like sharing points of view, forming well founded opinions and collective comprehension, doing activities that allow their participation. They pointed out that this is a key element in the development of the learning processes.

Table 5. Analysis of the students' answers about the conditions required to promote argumentation in the classroom. Source: The authors.

Dimensions	Category	Examples	Frequency group
Methodological aspects of the classes	Participation in the classroom from:	Group activities	2
		Use of contextual situations	4
		Lab experiences	4
		Teacher's methodology	3
Emotional aspects	Previous knowledge	Getting Informed and questioning the topic	5
	Disposition	Motivation of the students and of the teacher	4

The previous table summarizes various conditions that are necessary to promote the argumentation processes. For example, the situations of participation in the classroom are highlighted: the development of group activities and the use of contextual situations. The participants also mention several aspects such as the teachers' and students' disposition. More frequently, the participants indicate the need to know more about the topic, as, according to them, this aspect helps them to be able to question the information and improve the quality of the argumentative processes. They also acknowledge that in order to offer quality arguments, previous knowledge of the topic is required.

It can also be observed how students refer to the didactic knowledge of the content. On the one hand, there is the disciplinary knowledge, given that the participants mention the information that appears in the books which is to be questioned, and on the other hand, the process that requires its teaching in the classroom where subjective aspects of the students and alternative conceptions are implicit. The importance of class participation is highlighted, so as to share points of view, which is an important aspect of argumentation. This coincides with what was said by Sampson and Clark (2008), who pointed out that argumentation implies the disposition to participate and the dialog to support or refute an explanation. It also coincides

with what was indicated by Nussbaum (2011) that participation is built by means of a stimulation process that favors a profound comprehension of knowledge.

Below, some examples of the oral discourse are presented. The objective is to visualize the dialogical processes developed in the groups about argumentation in science. Neither the answers nor the expressions or the spelling mistakes are corrected. The clarifications appear in square brackets and in italics [*clarification*]. Some shifts or repetitions that are omitted are represented by parentheses.

By way of example, the comment made by Group B, responding to the question: “What is to argue in science?” is presented.

Chapter 1 – Group B

Betty: “Argumentation is different from opinion because an opinion is a point of view that you give, but it is very subjective. It is not centered on anything much consolidated, theoretically speaking. In contrast, with an argument you can take a stance with certain parameters to guide you and give a good presentation on the topic. It could be by criticizing, looking at the impact, relating with topics for a formal development, to build the concept that you want to deal with.”

Beatriz: “Argumentation has a theoretical basis and has, like, an approval whereas an opinion is a divulgation to get to build the argument.”

In this fragment, even when Betty makes emphasis on the need to get informed in order to offer a good presentation of the topic, she acknowledges the need to have an opinion as a mediating element of the argumentation, consolidated and based on a theoretical framework. Also, the participants highlight the need to have theoretical grounding and data to be able to argue and support ideas. In the previous fragment, for the students, it is possible to see that an opinion is intuitive whereas argumentation is a rational process that requires associations between concepts. They also mention an implicit element in the argumentation, which is, considering various different aspects or, as Betty puts it, evaluating the impact.

Analysis of the forms of argumentation from practical experiences in the laboratory

As a second aspect of interest in the study, an analysis of the quality of the arguments in laboratory practices was carried out. That implied the use of learned knowledge of natural science in order to explain the effects in the reactions observed in experimental practices.

The analysis of two of the questions proposed in the experience is shown below:

- a) What is the action of sodium bicarbonate?
- b) Why is trichloromethane used in the practice?

The answers to these questions are analyzed taking into account the three aspects of the forms of argumentation that were explained earlier in Table 3: content, structure, and forms of discussion. In order to analyze each one of the answers given to the two questions mentioned, the concepts and content elements that were evaluated in each one are presented:

Table 6. Criteria to evaluate the answers to questions from the experimental practice. Source: The authors.

Question	Minimum criteria for the analysis
What is the action of sodium bicarbonate?	<p>CONTENT OF THE ARGUMENT:</p> <p>Point out the type of coloration and the change in pH that occurs in the analyzed coffee.</p> <p>Evaluate if the students use concepts and data accurately in the experience, such as pH value, and if they are capable of relating them; for example, explain why sodium bicarbonate is an alkaline agent and its significance, sodium bicarbonate as electron donor. The use of NaHCO₃ allows for the extraction of organic acids, in this case, acids contained in the coffee, such as caffeic acid.</p>
Why is trichloromethane used in this practice?	<p>CONTENT OF THE ARGUMENT:</p> <p>Relate concepts, such as the density in the formation of two layers, considering the chemical composition of caffeine and chloromethane. Use the concepts of polar and non-polar compounds. Consider the structure of caffeine, given that in carbon chains of more than four carbons can easily be separated with organic solvents from the aqueous solutions. Use the concept of ionics, for example point out that ionic compounds are dissolved in polar solvents and the non-ionic compounds are dissolved in non-polar solvents.</p>

The analysis of the answers given by the students is done using this rubric. In the case of the first question, the following was found:

Table 7. Synthesis of the forms of argumentation in response to the question: What is the action of sodium bicarbonate? Source: The authors.

ASPECTS OF THE ARGUMENT	VALUE ASSIGNED	EXAMPLES	Frequency
CONTENT	3	"Sodium bicarbonate is an alkaline agent."	3
		"Sodium bicarbonate is a basic compound."	4
	2	"Sodium bicarbonate reduces the solubility of caffeine in coffee."	5
		"Sodium bicarbonate contains carbon and oxygen."	3
	1	"Sodium bicarbonate eliminates part of the aroma."	1
STRUCTURE		"Sodium bicarbonate eliminates liquid substances."	1
	3	"Sodium bicarbonate is an alkaline agent and, for that reason, neutralizes the acidity of the coffee and generates CO ₂ ."	3
	2	"Sodium bicarbonate is a basic compound, for this reason, it augments the pH of the coffee."	4
		"Sodium bicarbonate produces CO ₂ because it contains carbon and oxygen."	3
	1	"Coffee has a dark color because sodium bicarbonate neutralizes it."	2
FORMS OF DISCUSSION		- Proposes opposing ideas and supports them with concepts, data, and sources of information that go into detail and improve the argumentation in response to arguments that lack content or are incoherent.	0
	3	- Proposes concepts, data, and sources of information that go into detail and improve the argumentation in response to arguments that are coherent but incomplete.	
	2	In response to diverse arguments, proposes complementary ideas, but without supporting them with sources of information or using inaccurate concepts.	3
	1	The answer given by one of the members of the group is accepted, without going into detail.	9

The previous Table allows us to evaluate how the interventions of the students can demonstrate diverse concepts, but in a vague way. On a structural level, the concepts are not always used to respond to the question argumentatively. As a matter of fact, in the structure of the argument, we can see that to explain the effect of sodium bicarbonate in the experience, only 3 out of 12 students used the correct concepts such as alkaline, neutralization, and acidity. At the same time, only 4 groups out of 12 used concepts like basicity and pH properly.

We put "Sodium bicarbonate produces CO₂ because it contains carbon and oxygen" in the first level of the structure of the argumentation given that, even though this is true, this is not inferred from the practice where the extraction of caffeine is made. In fact, this argumentation is elaborated by the students by being inferred from other experiments (for example, the mix of acetic acid with sodium bicarbonate).

It is also concluded that there are no arguments that mention sodium bicarbonate (NaHCO_3) as an electron donor, nor arguments that mention its use for the extraction of organic acids. In general, it is observed that when it comes to a discussion, most of the groups tend to accept what is proposed within the group, with little supplementation, and no rejection.

In relation to the second question, “Why is trichloromethane used in this practice?” the content of the argument analyzes if the students explain why the use of chloroform permits the formation of two layers and why it facilitates liquid-liquid extraction. In the structure of the argument, it is expected of the students to relate concepts, such as the density in the formation of those two layers, and to use concepts like polar and non-polar compounds. They are also expected to explain that the structure of caffeine in carbon chains of more than four carbons can be easily separated with organic solvents from aqueous solutions, and that ionic compounds are dissolved in polar solvents whereas non-ionic compounds are dissolved in non-polar solvents.

Caffeine is quite a lot more soluble in an organic solvent than it is in water. So, by shaking the filter in contact with a certain volume of solvent in the decanting funnel, caffeine mostly passes to the organic phase. This is because the organic solvent is denser than water, which will form the lower layer, and it can be collected by simply opening the tap of the funnel. The glucose separates from the caffeine which is extracted in the organic solvent, in which glucose is not soluble. We make a synthesis in Table 8.

Table 8. Synthesis of the quality of the argument in response to the question about trichloromethane. Source: The authors.

ASPECTS OF THE ARGUMENT	VALUE ASSIGNED	EXAMPLES	Frequency
CONTENT	3		0
		“Trichloromethane is a solvent and allows for the formation of two layers.”	4
	2	“Trichloromethane forms two layers, like water and oil.”	4
		“Trichloromethane does not mix with water.”	1
		“Trichloromethane forms an organic and an inorganic phase.”	3
	1	“Caffeine is more soluble.”	2
	3		0
		“Trichloromethane and caffeine are separated due to the polarity that allows for the formation of two layers.”	2
		“Trichloromethane decaffeinate coffee because it is a solvent and allows for the formation of two layers.”	4
		“Immiscible mixtures are found”	1
FORMS OF DISCUSSION		“Increases the solubility of caffeine.”	2
	1		0
	3		0
	2		0
	1	The answer given by one of the members of the group is accepted.	12

The use of trichloromethane in the laboratory practice is very illustrative, as it permits the formation of two layers. As regards this, the students mention that the function of this compound is to dissolve the caffeine. This allows them to identify that there is no difficulty in establishing arguments with content in Levels 1 and 2, which shows that the students pay attention to the physical properties and the macroscopic level of the practice, but that they do not go into detail when it comes to the chemical analysis of the practice, nor the background concepts that this implies (density, polarity, etc.)

This has effects in the structure of the arguments because none of the groups reach a level 3 when establishing coherent relationships between the concepts. In effect, they use concepts like “organic and inorganic phase” without establishing relationships between them. Moreover, when what happened is explained using the concept of polarity, the students take it for granted and do not go into detail as regards its explanation.

With respect to this, they could direct the argument by pointing out that although caffeine is soluble in water, it is even more soluble in trichloromethane, and for this reason, it is extracted using this organic solvent. Thus, the extraction using this compound separates almost pure caffeine from the basic solution.

Below you will find an example of the conversation of Group K. It is noticeable that they included some concepts like polarity of the substances and interpretation of the boiling temperatures. This greatly supports the argument with structure.

44.Kilian: Second question: Why is trichloromethane used in this practice?

45.Kevin: Trichloromethane or chloroform is used in this practice because it separates the organic and

46.inorganic phases, it is a useful reactive given the polarization that is present in its links. This

47. helps a lot with the organic tuning of the compounds.

48.Kevin: Does it describe what happens in the distillation? Does the data concerning the boiling temperature coincide with

49. the one reported in the literature? Justify your answer.

The previous fragment allows us to appreciate that the students have a good command of some concepts (polarity, trichloromethane, organic and inorganic phase, and reactivity). These concepts are used as premises until line 47, but in line 48 the students move on to another question straight away. That shows a failure to establish relations between the concepts and the actual practice carried out on the coffee. Neither is there an interruption, refutation, or complement to what was said by Kevin.

Development of the didactic sequence based on an SSI related to the consumption of coffee

In order to analyze the answers given by the different groups, below you will find the criteria that will allow the classification of the students' answers in the different levels, in each of the sections in the didactic sequence (cf. *supra*, Table 2.)

Some of the previous sections were chosen for the analysis that is presented in this article, as shown in Table 9:

Table 9. Criteria for the analysis of the content of the arguments in the didactic sequence of the activities that are the object of this article. Source: The authors.

SECTION OF THE DIDACTIC SEQUENCE	ASPECTS	DESCRIPTION
		If the students:
THE CHEMISTRY OF COFFEE	CONTENT	Use data about the composition of each type of coffee (for example, phenols, proteins, aliphatic acids, and antioxidants) and their functions in the body.
UHT PLANTS	CONTENT	Take into consideration the concepts such as direct or indirect heating, energy efficiency, heat exchange surface, organoleptic properties of coffee, and sterilization of coffee.

Next, the results of some of the items that form the sequence are presented.

The chemistry of coffee

In this section, the students were presented with a table that contains information about the two types of coffee most consumed in Colombia: Arabica and Robusta. This allows them to investigate the advantages of each one, look up the function of the antioxidants in the body, the effect of free radicals, and the importance of chlorogenic acid ($C_{16}H_{18}O_9$). The main question that was made was what type of coffee they would prefer to consume, and why.

Below, a synthesis of the types of arguments found is presented.

Table 10. Synthesis of the forms of argumentation in discussions about the components of two types of coffee. Source: The authors.

ASPECTS OF THE ARGUMENT	VALUE ASSIGNED	EXAMPLES	Frequency
CONTENT	3	Robusta coffee contains antioxidants, chlorogenic acids, and therapeutic properties that reduce the levels of glucose and insulin.	4
		Arabica coffee contains less sugar.	1
	2	Robusta coffee contains more caffeine and less sugar than Arabica coffee.	3
		Arabica contains less antioxidants.	1
	1	Both types of coffee have good and bad attributes.	3
		"We prefer Robusta coffee because it contains antioxidants, chlorogenic acids, and therapeutic properties that reduce the levels of glucose and insulin."	4
STRUCTURE	2	"We prefer Robusta coffee due to its higher content of antioxidants that reduce free radicals."	4
		"We prefer Robusta coffee because of the carbon chains and the presence of chemical bonds."	1
	1	"We prefer Arabica coffee because it contains less sugar."	1
		"We prefer Arabica coffee because it contains more caffeine and less sugar."	2
	0	We prefer Arabica coffee because it contains less antioxidants.	1
		"Arabica is preferable because it doesn't contain as many antioxidants, because consuming so many antioxidants is bad for your health."	1
FORMS OF DISCUSSION	3	- Proposes opposing ideas and supports them with concepts, data, and sources of knowledge that go into detail and improve the argumentation in response to arguments that lack content or are incoherent.	1
	2	- Proposes concepts, data, and sources of information that go into detail and improve the argumentation. In response to diverse arguments, proposes complementary ideas, but without supporting them in sources of knowledge	1

	or using inaccurate concepts. The answer given by one of the members of the group is accepted, without going into detail.	
1		10

This aspect permits the evaluation of how a number of groups like C, H, I, and K, choose the type of coffee because of its antioxidant content. In the same way, other work groups choose the type of coffee because of its sugar or caffeine content. These approaches are valid because the students indicate that antioxidants inhibit the action of free radicals, helping to avoid cancer. The association and the effect that some components have in the body is analyzed; for example, explaining how antioxidants reduce the free radical content. The commentary of Group I is presented as an example.

GI. "We choose Robusta coffee because it has more antioxidants and chlorogenic acids, and they possess therapeutic properties that reduce the levels of glucose and insulin. The amount of caffeine, in this case, is not important because what matters is the quantity of antioxidants and the benefits for the body. The handling at the moment of roasting the coffee is important, given that many properties can be lost. It can also be altered by external factors in the preservation and storage of the coffee."

In the previous commentary, the association of diverse compounds is observed. They point out, for example, the effect of chlorogenic acid on the reduction of glucose. They complement their comment with aspects that must be considered, as regards the quality of coffee, related to its handling and storage.

In groups like J, it is shown that they are not clear on the concepts in the second sequence. For example, the group indicates that it is necessary to choose the type of coffee that has a lesser quantity of antioxidants. They justify this by saying that an excess of anything can cause damage, and they end the discussion making a choice simply based on the flavor.

55. José: In my opinion, I would choose Arabica that has less antioxidants.

56. Janeth: Why?

57. José: because, anyway, I consider that consuming so many antioxidants can also

58. be bad for your body, we already consume some foods that contain those

59. antioxidants. If you drink Robusta, I analyze in my head that it is the strongest and

60. Arabica, that is even stronger, well, it has at least twice the process, so I would prefer

61. Arabica.

62. Janeth: Well, no, I would make my choice because of the flavor, actually. Let's say,

63. you see the Table and the data, but I would be led more by the flavor, I would not know. Well, for me, that

64. would be valid, which of the two has a better flavor.

Thinking the argumentation processes from the use of technological mechanisms

In argumentation processes it is vital that the students reach conclusions that allow them to make decisions that have bases and promote actions for the improvement of the quality of life. It is also intended that they are capable of transforming their reality, resolving different situations on a personal, family, and work level. For this, the students were presented with a situation in order to consult the characteristics of each technological mechanism. The situation that was presented is the following:

Mario wishes to implement thermic treatments in his coffee industry. Considering the number of technological mechanisms that are offered in the industry, he requires the guidance of a professional in the natural sciences field to make a better decision. What recommendations would you give Mario?

In this way, they could suggest Mario, the character in the situation, which best type of *Ultra High Temperature* (UHT) plant is based on their training as future graduates in natural sciences.

Considering the answers written by the groups, the classification is presented according to the choices of the participants.

Table 11. Synthesis of the forms of argumentation in discussions about the choice of the type of UHT plant. Source: The authors.

ASPECTS OF THE ARGUMENT	VALUES	CATEGORIES	Frequency
CONTENT	3		
	2	They use concepts but without explaining their meaning (indirect heating).	3
	1	They do not use concepts.	9
	3		
	2	The one that uses indirect heating.	3
		The plant that produces a better-quality product.	3
STRUCTURE		The one that allows to obtain a more natural coffee.	2
	1	The treatment depends on the type of coffee required	1
		Textual transcription of the guide.	5
FORMS OF DISCUSSION	3	- Proposes opposing ideas and supports them with concepts, data, and sources of information that go into detail and improve the argumentation in response to arguments that lack content or are incoherent.	0
		- Proposes concepts, data, and sources of information that go into detail and improve the argumentation.	
	2	In response to diverse arguments, proposes complementary ideas, but without supporting them in sources of information or using inaccurate concepts.	0s
	1	The answer given by one of the members of the group is accepted, without going into detail.	12

Some examples of the responses are as follows:

GC. "We would recommend the UHT type P, given that it indirectly transfers the heat through the product when it is being heated and when cooled it does not apply, so a natural product is obtained."

The answer offered by Group C, corresponds to the transcription of the text that is presented in the guide, so there is no evidence of the association of the concepts learned. Other groups, like H, use general statements in their affirmation, such as pointing out that they choose the D type because it permits the conservation of the products properties and saves energy.

GH. "We would advise Mario to choose UHT plant type D, because it has a direct method of heating and because it allows for a very high quality of the product. The

comprehensive steam injection and the instant filtering allows for very brief time spent in the zones of intense temperature.”

Once the characteristics of the technological mechanisms are considered, Group D decided on a type I UHT plant, because of the advantages that it offers in regards to production and energy recovery.

Apart from that, the group adds that it has been one of the most broadly used mechanisms, and one of the most successful for a long time. The groups that chose a type P plant say they did it for environmental reasons.

Below, there is a discussion of one of the work groups of three students to choose the type of UHT plant.

- 94.Alberto: Well, that depends on what Mario wants to obtain from the coffee and on what he is looking for in
 95. the coffee, I would believe that each type of heating will determine different characteristics for the
 96.coffee. So, type I may give it more aroma, type P may give it a sweeter flavor, eliminate
 97. the acidity, type D may give it other different characteristics, so we should talk
 98. to Mario to know what it is that he expects from the coffee...thus, the science professional could
 99. make a recommendation.
 100.Antonio: in the case that it was to have a good quality product, and taking into account what
 101.was said in the reading, I would recommend the UHT plant D, as what it mainly does
 102.is to allow for a high quality of the product.
 103.Alex: but we should see what type of coffee Mario has, the characteristics that this
 104.coffee has, if this coffee works well with that plant or what treatment is best from the point of
 105.view of the coffee, and what Alberto says and the point of view of what he wants. If we are
 106.going to tell him, well I want my coffee to be mild, that it has these characteristics, and 107.these
 other characteristics, but that plant isn't suitable because it turns out that that plant cannot improve
 108.this coffee.

The previous commentary responds to the setting of the situation presented in the sequence in regards to general characteristics, but it does not use the concepts given in the description of each type of plant. For example, it is assumed that each plant produces one type of coffee. In the same way, Antonio mentions that he would choose the plant that produces a coffee of high quality, without going into detail.

This reveals the difficulty the students have in weighing the advantages and disadvantages of the types of UHT plants presented and to see their viability as regards scientific concepts. Here the students could also discuss: aspects related to the environmental impact that these types of technological mechanisms produce, and relate them to energy efficiency.

In conclusion, it is demonstrated that the students did not have a good command of concepts related to physics and, for that same reason, they did not know how to apply them, given that in the guide the characteristics of the UHT plants were explained, but none of the groups took it into consideration in a conceptual way¹.

DISCUSSION AND CONCLUSIONS

¹ Bachelors in Natural Science and Environmental Education must have a command of concepts related to biology, chemistry and physics. However, the students admit to having conceptual difficulties in chemistry and physics.

From the introductory guide to the need of the study of argumentation in the teaching of the sciences, it is observed that the groups acknowledge as a fundamental aspect the possession of theoretical references to be able to make effective argumentative processes. This implies giving relevance to the use of information as a necessary condition for the advancement of scientific knowledge and the validation of the arguments presented, reaffirming what was stated by Sarda and Sanmartín (2000).

This helps to make clarifications between opinion and argumentation. There are also categories in which argumentation is valued beyond the merely informative aspect, which constitutes a process for the students of the Bachelor's Degree in Natural Science to reflect upon their learning processes that are implicit in aspects, such as the relationships professor-student, student-student, and student-knowledge.

As regards this, studies by Mercer and Littleton (2007), Alexander (2006), Chi (2009) mention that students learn more efficiently when there is active participation in the activity through debate, dialog, and interaction. This coincides with the contributions of Sampson and Walker (2012) in the respect that the social process of learning implies articulation between the concepts, the language, the representations, and the practices that define science as culture.

The participants indicate that argumentation is a necessary process in the validation of ideas, and they acknowledge that argumentation has allowed for the advance of scientific knowledge and to bring about reflections so as to contrast one's own opinions with theoretical fundamentals. Similar aspects are pointed out by Dimopoulos and Koulaidis (2003), Oliveras *et al.* (2011), who affirm that argumentation permits a scientific and general literacy by linking social aspects in the study of scientific concepts.

The results presented in this study indicate that the students find it easier to answer the question about the effect of sodium bicarbonate in relation to that of trichloromethane. In the case of sodium bicarbonate, the students mentioned uses such as the preservation of coffee, neutralization of pH and reduction of solubility. In the second case, they mention characteristics like the generation of phases for decanting.

This aspect shows the need to question the use of all the reactive materials in the experimental practices, in order to procure a better association between what is observed, its meaning, and the use of scientific concepts. This aspect gives information about the comprehension of the scientific contents, reached by some of our students; in this case, some of the concepts are: chemical reactions, density, ionic and covalent compounds, and polarity.

This is in relation to the use of concepts that are specific to certain disciplines. However, the study carried out shows the need to strengthen the formation of future graduates in formal aspects so as to build arguments with a coherent and solid structure.

In spite of what is stated by Lunetta, Hofstein, and Clough (2007), that the practical work can be a learning experience where the students can understand concepts more easily, in this study it is observed that the lack of clarity as regards the concepts has an influence when there is confusion when it comes to the meaning of concepts in the experimental practice. For this reason, it is suggested that the quality processes of argumentation in the formation of teachers of scientific education are studied in depth.

It is acknowledged that the choice of the type of coffee is influenced by organoleptic characteristics. With respect to this, some students recognize the need to have a command of biochemical concepts to be able to evaluate the effects that each compound has in the body. Due to this situation, they decide on a type of coffee given the amount of caffeine. This segment allows them to recognize that the knowledge of the contents, or the lack of it, may distort the quality of the students' arguments. In the same way, no comments were made as regards the cost of each type of coffee (*Arabica* and *Robusta*). For example, in the market Arabica coffee tends to be more expensive as it has a milder and more pleasant flavor than

Robusta coffee, which has a more complex aroma, with lower acidity and caffeine (between 0.7 and 1.5%). For all of the above mentioned, Arabica coffee tends to be pricier.

In the results, it was observed that only 6 groups indicated that aromatic and volatile compounds are responsible for the aroma of coffee, yet a direct association of the volatile and aromatic concept with the type of enzyme reactions that take place for the aroma to arise is necessary. On the other hand, some of the reasons that are cataloged as the most distant ones to the question can be attributed to the industrial processes, the way the product is stored and the maturity of the fruits. Some reasons are mentioned, but they seem to hold no relation to the situation studied.

In this study, there were no arguments that described the type of aromatic compounds that are responsible for the aroma of coffee, such as thiazole and ethylphenol. In the same way, there are no established relationships with other types of processes like the effect of the temperature on the processes of lyophilization, or the effect of Maillard reactions and degradation, among others.

Actually, the commentaries do not allow us to link the effect of the roasting with the modification of the compounds and the properties of coffee, neither do they indicate the changes that the high temperatures produce in sugars, fats, proteins, non-proteic nitrogenized substances, and acids. With respect to this, Zuluaga (1990) says that the aroma and the flavor of coffee are developed during the roasting process. So, the composition of roast coffee depends on the level of roasting. In the coffee-roasting industry, that level is evaluated by measuring the light refraction of the grains or by visual inspection.

Finally, it is observed that the students present some difficulty in solidly justifying their affirmations based on scientific concepts. For this reason, it is necessary to make emphasis on the fact that argumentation goes beyond being an opinion and of being a merely informative action. It requires processes of association, deep knowledge of the topic, use of data, and theoretical sources that create spaces of uncertainty, which can be taken advantage of to formulate proposals for reflection within the pedagogic practices of the teacher trainers. It is about taking on the pedagogic practices from a transformational perspective and restructuring learning progressively toward the desired professional knowledge (Porlán & Martín, 1996).

In relation to the activities developed, it is possible to see that there is an absence of refutations in the conversations of the participants. So, it is essential to highlight how important refutations are in the scientific context, given that they constitute a way of improving theories of scientific knowledge and, from them, arguments are justified and questioned. The use of refutations constitutes a contribution to developing critical thinking in the students.

The results show how important it is that in the teaching and learning processes there is an emphasis on the assimilation of concepts demanded by each discipline. If not, the subjects would not have the theoretical references required to build and defend their argumentations in a solid way.

In the same way, the findings of this study seem to coincide with Penha (2012), who states that the development of argumentations in SSI spaces may lead to ideas getting too close to one another, which makes it difficult to have opposing perspectives. For this reason, it is necessary to use counterarguments that bring new aspects and other dimensions of analysis into discussion, to promote the participation of the students.

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Contribution of Mind Mapping, Summarizing, and Questioning in the RQA Learning Model to Genetic Learning Outcomes

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ABSTRACT

This study aimed to measure the contribution of summarizing and questioning in the Reading-Questioning-Answering (RQA) learning model integrated with mind mapping on the genetic learning outcomes. This study was a correlational research and has been analyzed using multiple regressions. Mind mapping, summarizing, and questioning were positioned as predictors, and genetic learning outcomes were positioned as a criterion. The research sample comprised 33 students. There was a strong correlation (97.4%) between mind mapping, summarizing, and questioning with the learning outcomes. The value of the relative contribution of each predictor (questioning, mind mapping, and summarizing) was 58.74%, 39.76%, and 1.50%, respectively. The value of the effective contribution of questioning, mind mapping, and summarizing was 57.21%, 38.73%, and 1.46% respectively. Thus, the contribution of questioning was higher than that of mind mapping and summarizing on the genetic learning outcomes. Future studies need to be conducted in order to confirm these research results.

Keywords: Learning model, mind mapping, questioning, reading-questioning-answering, summarizing.

INTRODUCTION

The Reading, Questioning, and Answering (RQA) learning model is a learning model that has been widely studied in all levels of schools and universities (Zunaidah, 2015; Bahtiar, 2013; Rahmawati, 2014). The syntax of this learning model has three steps, namely Reading (the students summarize the learning material), Questioning (the students make questions based on the summary), and Answering (the students answer those questions). The three syntaxes were performed prior to the classical teaching and learning processes (Corebima & Bahri, 2011).

Studies conducted on learning models such as RQA are usually related to learning model on learning outcomes as a unity. For example, the effect of RQA as a whole on metacognitive skills (Hasanuddin, 2013), learning activities (Rahmawati, 2014), thinking empowerment (Mulyadi *et al.*, 2014), critical thinking (Priantari, 2014), higher order thinking,



science process skills, and retention (Sumampouw, 2011). According to our research, no study has investigated the contribution of each element, such as of reading, questioning, or answering, to the learning outcomes separately. This study attempts to measure the contribution of summarizing and questioning separately to the learning outcomes.

Research on RQA has not been widely developed in other countries outside of Indonesia because the dissemination of the research results did not spread enough. In fact, this learning model is very good to be implemented considering its syntax that is needed by educators in all types and levels of education. RQA is designed on the assumption that every student should have sufficient knowledge before entering the classroom. This knowledge can make a major contribution to learning interactions because the students already have knowledge about the learning material that will be taught by the teachers. This initial knowledge is further enriched during the learning process and is also confirmed by other concepts.

The initial knowledge of students gained during composing a resume during the phase of “reading” is obtained from the reference that has been recommended to be read. Based on the reading results, questions will arise as a result of the cognitive interaction between students’ new knowledge and previous knowledge. The students then answer these questions on the basis of the depth of their knowledge.

In this study, new syntax was added in previous RQA, namely the phase of mind mapping as a preliminary research outcome obtained before the genetic learning. The preliminary research was conducted for three semesters before the main study was carried out at the State University of Malang and the University of Jember, (Hariyadi, 2015a). The results of the preliminary research showed that the implementation of RQA by the students had not been optimal. The students’ ability of summarizing the initial syntax of RQA had not met the standards. They only took some phrases or sentences in the articles and rearranged them into paragraphs during the summarizing process. In fact, a summarizing should be original (using the writer’s own language and expression), concise (much shorter than the text), accurate (reveal the main idea), objective (exclude the opinion of the author), and complete (convey the whole idea) (Kirsznner & Mandell, 2013).

In relation to these results, the researcher considered using a certain technique as a mediator to make the summary. The technique was mind mapping. According to Buzan (2015) this technique provided the students a space to capture the essence of the concept and to write the key words and concepts that interconnect between one another in the form of associations and connections. Moreover, according to Hariyadi (2015b) mind mapping contains the key words of a discussion that is arranged in the links from the main concept, branching into the related sub-concepts. Solas & Wilson (2015) stated that mind mapping was helpful for enhancing the artistic and creative abilities of students and it required limited language use in order to force students for organizing information by making associations between concepts; this resulted in the student engagement increase and helped to retain student focus. Based on the mind mapping patterns, the students can summarize the learning material easily and coherently. Thus, in this study mind mapping technique was integrated with RQA.

Importance of the study

Genetics is a very important course for understanding the biological phenomena comprehensively, in accordance with the opinion of Theodosius Dobzhansky who said that it is impossible to understand Biology without the enlightenment of Genetics (Ayala, *et al.*, 1984). The understanding of the concepts of Genetics will greatly help in the understanding and development of other branches of Biology. Thus, it is imperative to design a research related to learning models that can trigger a comprehensive understanding of Genetics. Moreover, in this study, each part of the learning model is partially examined in terms of its

effect on the learning results. Thus, the most influential of the syntax can be found. This information will give contribution greatly to the research on other learning models, such as Think-Pair-Share and Two Stray-Two Stay.

Aim

This study aimed to measure the contribution of summarizing and questioning in the RQA learning model integrated with mind mapping to the genetic learning outcomes, using a quasi-experimental research design. These research results are very important to improve this integrated learning model further.

METHODS

This study was conducted as a part of dissertation research regarding the effect of the RQA learning model and Project Based Learning on the critical thinking skill, metacognitive skill, and cognitive learning outcomes in different academic abilities. This research is a quasi-experimental research conducted in two Genetics classes using pretest posttest nonequivalent control group design of 2 x 2 factorial design. The participants of this research were the students of Biology Education, Faculty of Teacher Training and Education, University of Jember, 2015/2016 academic year. In this connection, there were two classes of which one class was taught with RQA learning and the other was taught with conventional learning. In the two classes, there were students of high as well as of low academic ability. The two classes were previously tested for an equality test. The instruments used in the quasi-experimental research were learning media, essay test (to measure the cognitive learning result, critical thinking skills, and metacognitive skills), including its rubrics related observation sheet as well as a questionnaire to uncover the responses of teacher and students. All the instruments have been validated. Related to the essay test, a reliability test was conducted as well. However, this article was written based only on the data of the RQA learning model, especially related to the contribution of each syntax of RQA on the learning results. Those data used are derived from 33 students (25 females and 8 males).

In this study, the correlation analysis was conducted between mind mapping, summarizing, and questioning and the final value score of the study. The final value score was the total of the scores of the seven components, namely the scores of mind mapping, summarizing, questioning, learning participation (during the process of discussion, presentation, questioning, and answering), lab practicing (classical and independent project), midterm exams, and final exams. The data were analyzed using multiple regressions. Before the hypothesis testing, normality tests (by Kolmogorov-Smirnov) and the homogeneity of variance test (by Levene) was carried out. The analyses were carried out using SPSS version 17 for Windows with a significance level of 0.05 ($p < 0.05$).

FINDINGS

As part of the normality tests, the One-Sample Kolmogorov-Smirnov Test showed that the significance value of mind mapping, summarizing, questioning, (M-S-Q) and the learning outcomes was 0.903, 0.448, 0.588, and 0.758, respectively. These results indicated that the values of mind mapping, summarizing, questioning, and the learning outcomes were normally distributed.

The results of the multiple regression correlation analysis showed that the $F(3, 29) = 368.108$, $p < 0.05$ (Table 1). The value of the multiple regression coefficients (R) was 0.987 with a contribution value (R^2) of 0.974 (Table 2). The R value of 0.987 indicates a strong multiple correlation between mind mapping, summarizing, and questioning at one side and the learning outcomes at the other side. Moreover, the 0.974 value of R^2 showed that mind

mapping, summarizing, and questioning simultaneously gave contributions as much as 97.4%, while the remaining 2.6% was influenced by the other predictors that were not investigated.

Table 1. *Multiple Regression Correlation on the Learning Outcomes*

	Model	Sum of Squares	df	Mean Square	F	Sig.
1	Regression	378.308	3	126.103	368.108	.000 ^a
	residual	9.935	29	.343		
	Total	388.242	32			

Table 2. *The Value of Multiple Regression Coefficients*

	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	0.987 ^a	0.974	0.972	0.585	1.759

The results of the multiple regression equation analysis of the correlation between summarizing, questioning, mind mapping and the learning outcomes showed that the regression equation is as follows: $Y = 19,529 + 0,252X_1 + 0,256X_2 - 0,239X_3$ (Table 3). The contribution value of each predictor toward the learning outcomes is that mind mapping gives a relative contribution of 39.76%, summarizing gives a relative contribution of 1.5%, and questioning gives a relative contribution of 58.74%. Thus, the total relative contribution is 100%. The effective contribution of mind mapping, summarizing, and questioning is 38.73%, 1.46%, and 57.21%, respectively. Thus, the total effective contribution to the learning outcomes is 97.40% (Table 4). These results indicate that questioning has the biggest contribution in explaining the learning outcomes compared with mind mapping and summarizing.

Table 3. *Coefficients*

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tol	VIF
1 (Constant)	19.529	1.749		11.168	.000		
Summarizing	.252	.023	.386	10.815	.000	.692	1.444
Questioning	.256	.026	.358	9.682	.000	.644	1.553
Mind Mapping	.239	.019	.462	12.560	.000	.653	1.532

Dependent Variable: Score

$r_{X1-Y} = 0,784$

$r_{X2-Y} = 0,794$

$r_{X3-Y} = 0,838$

Table 4. *Relative Contribution and Effective Contributions of Variables*

Variable	RC (%)	EC (%)
X 1 (Mind Mapping)	39.76	38.73
X 2 (Summarizing)	1.50	1.46
X 3 (Questioning)	58.74	57.21
Total	100	97.40

RC = Relative Contribution; **EC** = Effective Contribution

DISCUSSION and CONCLUSION

The correlation between M-S-Q and the learning outcomes

Technically, the implementation of M-S-Q is the first asset to form concepts before students carry out discussions, presentations, and question-answers in the class. In addition, M-S-Q provides prior knowledge before implementing a class practicum or independent project practicum. Any discussions that occurred during the discussion session were closely related to the material from which the students made the summaries, and the question answers. Thus, the students will be more focused on elaborating the material of the results of the personal study prepared before the teaching and learning activities so that it causes the value of M-S-Q simultaneously contribute 97.4% toward the learning outcomes.

On the basis of the results related to mind mapping and RQA, it can be concluded that both lead to an improvement in the learning outcomes. According to Liu, *et al.* (2014), the use of mind mapping gives a good effect in improving teaching and learning activities. Similarly, Whitman (2015) stated that the results of mind mapping strongly supported the test results because the students used visual skills, logical reasoning, and abstract thinking, promoted meaningful learning, and allowed the presentation of new material to build in the existing knowledge. Furthermore, according to Mulyadi *et al.* (2014), the cognitive learning outcomes of students using the RQA model led to a significant increase. This condition is in line with Corebima & Bahri (2011) who stated that the RQA learning model improved students' metacognitive skills, improved their concepts 14.38% higher than those using traditional learning, and even improved the concept gaining ability of the low academic achievers 59.96% better than those of high academic achievers experiencing traditional learning.

The contribution of mind mapping on the learning outcomes

The creation of mind mapping by the students was carried out during the pre-learning activity before summarizing. Each student was required to make up the main points of the concept of the material from various reading sources, which were arranged into a stratified chart, ranging from the main concept and the supporting concepts to the explanatory concepts. By using mind mapping, summarizing becomes more effective because mind mapping is designed to summarize written material (Farrand *et al.*, 2002), to make it easier in writing the main points to be arranged into a short essay, intertwined into one intact concept, and to be the ideal tool to clarify concepts (Peet, 2001).

The process of understanding the concept as a whole is a personal process that plays a role in building knowledge because mind mapping requires the central idea in advance (O'Connor, 2011). Next, the key ideas are developed (Riswanto & Putra, 2012) followed by the development of the related ideas radiating out from the central idea (Aykac, 2015). Thus, mind mapping requires an understanding of the whole concept, followed by analyzing it into personal concepts, and then representing it into a spider diagram or a hierarchical list (Prunckun, 2015). This way, it is arranged in an exact technique like how the brain functions radiating (Buzan, 2015). It is natural that mind mapping has a significant contribution toward the learning outcomes because it overcomes misunderstandings, supports the understanding of the concepts as a whole (Akinoglu & Yasar, 2007), and increases the long term memory of factual information (D'Antoni *et al.*, 2010).

The contribution of summarizing on the learning outcomes

Summarizing is the second syntax after mind mapping composition. The concept that has been summarized in a mind mapping chart form becomes the main reference in drafting a resume. Summarizing is the process of making the shortest representation of the original information source (Stein *et al.*, 2000). The advantages of a resume as the product of a

summarizing process are that it is concise, accurate, objective, and complete; moreover, it is original because it uses the writer's own words and not the words obtained from the reading source (Kirsznar & Mandell, 2013). As a result of using their own words in making the resumes, the students can experience barriers in the interpretation that is different from the original concept. Moreover, many students did not abide by the use of mind mapping while summarizing. This deviation caused the contribution of summarizing on the learning outcomes to be the smallest one.

Based on the results of the research, most of the resumes constructed by the students did not follow the guidelines of mind mapping. Their works did not have a coherent understanding. The main ideas did not have explicit meanings. There were some students who copy-pasted from resumes available on the internet. Several models of resumes were found to be very short because they only described the key words in the mind mapping. Some resumes looked like a long essay but did not show any link between concepts. The best resumes were the ones that were brief and yet were able to interconnect the concepts, thus giving a clear understanding. Related to the sentence structure, many students used their own words, especially for **certain** learning materials that were of less information. For the materials that were rich in information and contained many theories, some resume contained students' own words as well as text words, but some resumes seemed to be copy-pasted from the internet. These facts indicate that the students do not experience yet a conceptual change (Duit & Treagust, 2003; Pelamonia & Corebima, 2015) when making a resume. They still made the resume in the same way as before and did not use the guidelines of mind mapping.

In fact, the idea of preparing a resume using mind mapping is an effective way to control the formation of concept maps well and in an integrated manner. The weakness of this solution is the interpretation of foreign text, consistency of ideas when extracting the description of the concept in single or short sentences in mind map, and the interpretation deviation when preparing a resume using their own sentences. This causes a lower contribution of the summarizing than that of mind mapping.

The contribution of questioning on the learning outcomes

The questions raised during the process of summarizing were induced since the construction of mind mapping. To do a mind mapping, the students must understand the main ideas of the assigned reading and then create a resume. During that process, the students experienced the process of reading, processing, understanding, analyzing, and synthesizing the content of the reading. Next, they created a chart containing keywords and placed them into a mind map that was interconnected and intact. These sequences of processes can generate questions related to the unclear concepts, not yet understood concepts, incomplete concepts, or those causing confrontation with other concepts. Based on this phenomenon, a list of the questions and answers was compiled as per the students' mindsets. These questions also become the subject of the question and answer process during the discussion in the classroom so that the learning becomes more dynamic. When only relying on personal awareness to ask questions without the preparation related to prior knowledge, it will take a long time and the students will be less responsive. According to Zee *et al.* (2001), many students wanted to ask questions if their teachers asked them to do so. In fact, many teachers chose not to offer questions, so that students rarely asked questions. In this regard, it appears that the thinking process in the M-S-Q phase is quite essential, causing the students to do learning interaction more easily, due to the fact that the questioning activity has a higher score than those of mind mapping and summarizing.

Questioning is an important aspect that will trigger further curiosity (Calaprice, 2011), will develop creativeness and criticism ability (Ali, 2005), will result in students learning

more things, will induce an alternative answer in understanding a concept (Walsh & Sattes, 2011), and will increase the students' involvement in the learning interactions (Campbell & Mayer, 2009). Furthermore, questioning is an indicator of a self-concept mastery about science if students understand scientific questions (Çoban, 2011). Questions can be used as techniques in cross-culture studies in science education (Ali, 2016). In questioning, the elements that appear are derived from the cognitive conflict between the received concept and the prior experience, as well as between the prior knowledge and the personal beliefs (Hariyadi, 2014). If there is a good synergy between these elements, there will be a good process of understanding of the material. If there is a cognitive polarization, there will be divergence of concept leading to problems, that will induce the emergence of questions. Thus, questions are an important force in exploring knowledge compared with simply reading factual information provided in books. Questions can also be a medium to realize ideas or opinions, which can affect the learning outcomes. In this regard, it is shown that the thinking process in the MRQ phase is significantly important and makes the students able to do learning interaction more easily; hence, in this research the questioning phase has higher value than the mind mapping and the resume phase.

Suggestions

Mind mapping, summarizing, and questioning (M-S-Q) during the pre-learning process gives a significant contribution (97.4%) to the learning outcomes. Questioning gives the highest contribution because in this phase, the students find the sources of the problems during the pre-learning process. The second highest contribution is that of mind mapping because it extracts the main points of reading that requires extensive knowledge. The lowest contribution is that of summarizing because it only paraphrases the main concepts that have been developed; the students did not experience the process of deepening and widening of thinking. On the contrary, the students have not experienced a conceptual change from what has been believed so far; due to which they do not take advantage of the mind mapping charts to summarize, and instead, they summarize the text in their own way, which is by taking parts of the paragraphs that are considered important and arranging them into a summarizing product.

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Impacts of the Use of a Digital Simulation in Learning Earth Sciences (the Case of Relative Dating in High School)

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ABSTRACT

In an attempt to evaluate the impact of the use of a simulation on the learning concepts of relative dating, a study was carried out with first year students at the Technical High School of the city of Taza (Morocco). The method of the study was semi-experimental research design with pre-test and post-test. The study used two groups including the experimental (n = 16) and control (n = 16) groups. The learning outcomes of both groups of students were compared and analysed for significance using the Student's t-test and the Mann-Whitney U test. The findings showed that the integration of a simulation of relative chronology can have a positive effect on students' learning if it is properly integrated at an appropriate time during the students' training.

Keywords: Earth Sciences, relative chronology, high school, learning, simulation.

INTRODUCTION

Information and Communication Technologies (ICT) bring innovative means, not only for the transmission of knowledge, but also for the exploration of training strategies, which promote the development of competences (Lebrun, 1999 ; Perreault, 2003). Some interesting research has focused on the pedagogical utility of the use of educational software. (Bransford *et al.*, 2000; de Jong *et al.*, 1998). These technologies showed a great potential to improve students' learning if they are well integrated in an applicable educational context. These tools, among others, facilitate the use, the treatment and the production of information (Bransford *et al.*, 2000; Depover, *et al.*, 2007; Kutluca *et al.*, 2010).

Among the most promising means in the teaching of experimental sciences, we certainly find simulations intended for learning in face-to-face or in the context of distance education (Bibeau, 2005). These educational applications can simulate real phenomena while creating models or virtual experiments, allowing learners to control the variables, to formulate



some hypotheses, to interpret data and to facilitate the understanding of the complex phenomena (Roth et al., 1993; Rutten et al. 2012; Droui et al., 2013). The simulations are also considered like a tool for the resolution of the problems (Droui et al., 2015) and an alternative to the inaccessible experiments (De Jong, 1991; Strauss et al., 1994).

Several studies in teaching are interested in the use of computer simulations in the teaching of sciences to further promote learning. In this perspective, the use of simulations is very appropriate for carrying out simplified procedures and cognitive tasks (Grabe *et al.*, 1996) and reducing the gap between the dynamic and complex reality of the phenomena under study and their simplified and static teaching in class (Wilensky *et al.*, 2000). In addition, simulations can activate basic procedural skills in science students, such as observing, measuring, communicating, classifying and predicting (Roth *et al.*, 1993), as well as procedural skills integrated into the scientific approach, like controlling variables, formulating hypotheses, interpreting data, experimenting and formulating models (Padilla *et al.*, 1983). Lazarowitz and Huppert (1993) have reported that computer simulation used in biology can allow the students to use the skills of graphic communication, data interpretation and variable control in simulated experiments, besides helping them improve these skills. Simulation can also be considered as an intermediate level between theoretical models and the material manifestations of the phenomena studied (Richoux, Saveltat and Beaufils, 2002). The use of students' geometric optics simulation software for understanding lens imaging has shown that simulations can play the role of a 'cognitive bridge' between theory and experiment (Buty, 2003).

Moreover, simulation can be used as an additional tool in the laboratory. For example, the combination of simulations and laboratory experimentation can save time by reducing the duration of the laboratory session (McKinney, 1997; Kennepohl, 2001; Gibbons *et al.*, 2004), support laboratory familiarisation (Dalgarno et al., 2009) and ensure a better understanding of the basic techniques and concepts used in laboratory work (Martínez *et al.*, 2003). In addition, simulations are not only useful for modelling systems that are difficult for students to observe in real life, but they are also more powerful in influencing the learning process when combined with real experimentation (Martin, 1997; Nuhođlu *et al.*, 2007).

The use of simulations is the most promising alternative for experiments that we cannot achieve in the classroom (Mintz, 1993). In this sense, Strauss and Kinzie (1994) point out that simulations replace dangerous or costly experiments. Simulation can play an important role in providing opportunities to do virtual experiments. Moreover, problem-based simulations allow students to carry out their own experiments by formulating hypotheses and confronting them with observations, as well as build new knowledge and make sense of what they are learning (Droui, 2014).

Simulation provides scientific investigation environments and cognitive tools needed to apply problem-solving skills. It allows students to explicitly develop metacognition, and it allows them to reflect on their learning (Droui, 2014), to improve motivation and interest in the classroom (Martínez *et al.*, 2003) and to present themselves as an effective prediction tool (Lavoie *et al.*, 1988). And since non-verbal representations stimulate brain activity (Clements and McMillen, 1996), simulation can multiply the forms of representation (images, animations, graphs, and numerical data). By allowing the learner to choose the representations he or she prefers, it allows the learner to individualise learning, increase motivation and follow in the footsteps of learners during their learning (Cholmsky, 2003).

Simulation occupies an important place in Earth sciences. According to Stengers (1993), a new perspective is opened up by the computer as a simulation tool to study certain phenomena that are not reproducible in the laboratory. It is possible to work on small or large samples. When one is confronted with difficulties in understanding the dynamics of complex geological phenomena, it makes it possible to apply an explanatory model to a geological

event of the past, and thus reconstruct a geological history of a sedimentary region. It also enables forecasting and studying the future development of a phenomenon (Sanchez, 2007).

Statement of the problem

Didactical research concerning the teaching of Earth sciences is not abundant in comparison to those that concern the teaching of other experimental sciences. However, they convergently reveal the learning difficulties and obstacles facing the students during the assimilation of the geological data (Ault, 1994; Sanchez, 2008), in terms of understanding several complex geological phenomena related to stratigraphy, paleogeography, etc. ..., these difficulties are largely associated with the reports that the discipline maintains with time and space (Gould, 1990).

The difficulties associated with the relationship between the Earth sciences and time are as follows: difficulties understanding the immensity of the time during which geological events take place, difficulties developing a diachronic reasoning (Dodick and Orion, 2003; Sanchez, 2003), grasping the role of contingency in geological history (Gould, 1990), and understanding the dynamics of phenomena whose observation is inaccessible due to slow production (Raab *et al.*, 2002) and to fixism, which constitutes a major obstacle to the understanding of dynamic phenomena that seem static on a human scale (Monchamp *et al.*, 1995). Learning difficulties in geology are also linked to the relationship between discipline and space, i.e. the difficulties understanding the different scales involved (Trend, 2000), getting oriented in space, moving from two-dimensional representations to three-dimensional representations or changing the reference frame of observation (Sanchez *et al.*, 2006; Lamarti *et al.*, 2009).

Overall, many learners have difficulties grasping the concepts of geological time (Yoon *et al.*, 2015). Dodick and Orion (2003) assert that an essential objective of geology is the reconstruction of the geological structures and systems that have been developed over time. Therefore, learners need to understand the geological time to deepen their understanding of the Earth's structure and systems. In order to overcome the learning difficulties that make students dislike and undermine the Geology subject (Gohau, 2001; Dodick *et al.*, 2003), Earth sciences teachers are urged to integrate technological innovation into their teaching practices.

This paper is a study in which students use a computer simulation (Chronocoupe) to overcome some of the difficulties associated with the assimilation of the concept of relative chronology in the Earth sciences. Chronocoupe is a numerical simulation that allows the learning of the relative chronology of the Earth sciences. It was developed by Gilles Fuxa and Eric Sanchez. It is free for educational purposes. We have chosen this tool because of its advantages: ease of use, conformity of the content to the official school program, the scientific reliability of its content and the good educational and instructive quality. Moreover, this pertinent simulation has been proposed for several years as an educational aid for candidates applying for the aptitude certificate of Second Degree Professorship in France.

The integration of the ICT in teaching is accompanied by a constant questioning of the expected and potential effects of these tools on the learning process. Studies related to pedagogical use of simulations show that these digital resources are useful for students' learning (Rutten *al.*, 2012; Smetana *et al.*, 2012). Based on these studies, in this research, it is aimed to determine the effect of the use of a digital simulation in learning Earth sciences (the case of relative dating) and to compare students' success. Accordingly, this study is an attempt to answer the following questions:

- Would the enrichment of the course of reconstruction of the geological history of a region based on the principles of relative dating by a computer simulation have a positive effect on the output of the students?

- Would it reinforce the development of certain cognitive operations?
- Could the pedagogical use of such tool help learners overcome learning difficulties related to the concept of relative chronology?

METHODOLOGY

In order to identify the benefits of using ICT and in order to evaluate the impact of the use of simulation on learning, a semi-experimental design using a pre-test and a post-test was used. The experiment was carried at the technical school of Taza (Morocco). A sample of 32 students, from the first year of the baccalaureate, was chosen to participate in the study. The students were 17 years old. The experiment included two groups representing two different classes from the same school. The experimental group included 16 students, and the control group included 16 students.

The two groups of students received part of the course of geology corresponding to the relative dating under the same conditions of teaching respecting the official instructions. Then a pre-test (Appendix 1) was used with the two groups to make sure of their equivalence. This test is composed of five questions: the first one includes two closed sub-questions with a single choice, the second and third questions are closed – ordered answer category while the last questions are open. This instrument was developed and piloted with 15 pupils, and its reliability was estimated using the Cronbach alpha coefficient of internal consistency. It was found to have a reliability score of .780, indicating an acceptable reliability coefficient.

Then we opted for problem-based learning (PBL) to further strengthen students' cognitive skills by encouraging them to be more active and self-reliant. Students in both groups faced the same problem of reconstructing the geological history of an area from a geological section. Accordingly, the students had to apply the principles of relative dating based on an analysis of geometric relationships between geological structures to infer the relative chronology of the region. This pedagogical activity was guided by the teacher, who played a facilitating role.

During this activity, the control group solved the problem without using any computer environment, whereas the experimental group had the chance to solve the problem using a numerical simulation (Chronocoupe). This tool (cf.: figure 1) is a simulation designed to learn the methods used to establish a relative chronology. The learners are placed in a problem-solving situation to reproduce images of geological sections. This work leads them to determine the geometric relationships between geological structures, propose hypotheses on the relative dating of geological events at the origin of these structures and test these hypotheses by simulating their consequences. The educational software was exploited in binomial by a computer in the multi-media room of the establishment.

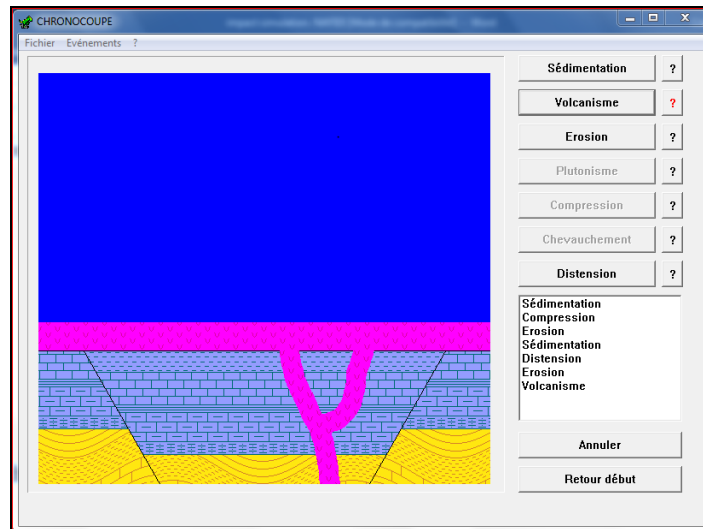


Figure 1. Screenshot of Chronocoupe (simulation developed by Gilles Fuxa and Eric Sanchez)

After finishing the teaching activity suggested, we invited the two groups to answer the questions of the post-test in a paper-pencil form (Appendix 2) to compare their answers. This post-test consists of six questions. According to Bloom's proven taxonomy, the first question, consisting of two closed multiple-choice sub-questions, is about knowledge acquisition, while the closed questions (2, 3, 4) and the open questions (5 and 6) are about application. At this level, the student must apply concepts in new situations and solve problems by investing the skills and knowledge required for relative chronology. The construction of the post-test was made by taking account of the program and the contents of the activity of PPBL suggested. This instrument was piloted with 15 pupils, and its reliability measured using the Cronbach alpha coefficient was satisfactory (α of Cronbach=0,709).

The data collected was then analysed with IBM SPSS statistics (statistical analysis software). The descriptive statistics, the Student's t-test (Gilbert *et al.*, 1992; D'hainaut, 1975) and the nonparametric Mann-Whitney U test (McKnight *et al.*, 2010; Nachar, 2008) were used to compare the groups representing two independent samples. A level of alpha of 0.05 was used throughout the analysis of the findings.

FINDINGS

a) Results of the pre-test

The results of the pre-test of the two groups are presented in Table 1 below:

Table 1. Descriptive statistics (pre-test)

	Control group	Experimental group
N	16	16
Minimum	6,00	8,50
Maximum	18,00	18,00
Mean	13,6094	14,0625
Standard deviation	3,41195	2,74393
Variance	11,641	7,529

It arises from the analysis of these results that the average score of the students of the experimental group in the pre-test is $m = 14,06$ ($s = 2,74$) whereas that of the students of the control group is $m = 13,60$ ($s = 3,41$); the difference is about 0.45. To check if this difference is significant and to reject the assumption that any significant difference did not exist between the two groups at the time of the pre-test, we used the t-test of the students to compare the averages of two independent samples having a normal distribution (p-been worth of Shapiro-Wilk is 0.068). The results of the comparison are presented in Table 2:

Table 2. Independent Samples Test (pre-test)

	Levene's Test for Equality of Variances		t-test for Equality of Means				
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Equal variances assumed	,355	,556	-,414	30	,682	-,45313	1,09461
Equal variances not assumed			-,414	28,680	,682	-,45313	1,09461

According to this table, the p-value of Levene's test is $p = 0.556$, which is non-significant; the variances can be regarded as homogeneous since their difference can be explained by a pure result of the chance. The p-value of the t-test higher than the level alpha is chosen, one p-value of 0.68 does not involve rejection of the null hypothesis; one can, thus, estimate that there is not a significant difference between the groups tested, which is explained by the use of school management system, 'MASSAR', whose aim is to ensure equivalence between the groups at the time of the constitution of the classes. This result enables us to validate our experimental model based on a pre-test and a post-test.

b) Results of the post-test

The results of the post-test of the two groups are presented in Table 3 below:

Table 3. Descriptive statistics (post-test)

	Control group	Experimental group
N	16	16
Minimum	7,00	11,25
Maximum	18,25	18,25
Mean	12,5000	15,1406
Standard deviation	2,90689	2,35932
Variance	8,450	5,566

The results show that the average of the students of the experimental group in the post-test is $m = 15.14$ ($s = 2.35$) whereas that of the students of the control group is $m = 12.50$ ($s = 2.90$); the difference is about 2.64. To check if this difference is significant and to reject the

null hypothesis that the tested educational device had no effect on the results of the pupils, we used the t-test of the students to test the difference between the averages of two independent samples having a normal distribution (p-value of Shapiro-Wilk is 0.315). The results of the comparison are presented in table 4:

Table 4. *Independent samples test (post-test)*

	Levene's Test for Equality of Variances		t-test for Equality of Means				
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Equal variances assumed	,317	,577	-2,821	30	,008	-2,64063	,93596
Equal variances not assumed			-2,821	28,782	,009	-2,64063	,93596

According to this table, the variances can be regarded as homogeneous; the p-value of Levene's test is $p = 0.577$, which is non-significant. The p-value of test-t is largely lower than the level selected alpha ($p < .05$); one p-value of 0.008 (less than 9 chances out of 1000 to be mistaken by affirming that the two groups differ significantly between them) enables us to reject the null hypothesis and thus to admit that the integration of the digital simulation in a situation of training of the relative chronology certainly had a positive effect on the output of the students. The teaching application used in this case obviously improved the results of the students of the experimental group because it was effectively integrated at the appropriate time. This finding is in alignment with the findings of former studies conducted in the Moroccan educational context that highlighted the positive impact of the use of the digital simulations on the output of students in other experimental disciplines (Droui *et al.* 2013; El Hassouny *et al.*, 2014).

In order to determine the effect of the integrated simulation on the development of certain cognitive processes of the students in keeping with the relative dating (the acquisition of knowledge and the application), we used the Mann-Whitney U test (in this case the distribution of the values does not follow the normal distribution because p-value of Shapiro-Wilk is lower than the level selected alpha) in order to compare the results got by the students according to each item of the post-test. The results are presented in Table 5:

Table 5. Mann-Whitney Test for Independent Samples (post-test)

	Q1	Q2	Q3	Q4	Q5	Q6
Mann-Whitney U	120,00	96,00	100,50	123,00	51,50	58,50
Wilcoxon W	256,00	232,00	236,50	259,00	187,50	194,50
Z	-,421	-2,099	-1,070	-,224	-3,228	-2,682
Asymp. Sig. (2-tailed)	,674	,036	,285	,823	,001	,007
Exact Sig. [2*(1-tailed Sig.)]	,780	,239	,305	,867	,003	,007

According to this table, the difference between the groups is not significant ($p = 0.780$) concerning the questions concerned with the first item; thus, the simulation used did not have an added-value in terms of the acquisition of knowledge, which highlights some limitations of the application used. Contrary to this result, Joubert *et al.* (2000) concluded in a study related to the use of simulations in teaching Newtonian mechanics that those simulations allowed an improvement of the students' knowledge and that the latter showed more precision in their reasoning.

In terms of the items testing the cognitive operation of application, the difference between the groups was non-significant ($p > .01$) compared to items 2, 3 and 4 including simple situations of application, with satisfactory success rates for the two groups. Equivalence between the groups in this case is probably due to the nature of the sample (it includes mathematical sciences students) or to the classical situation of training, which was also relevant and effective support the training of the students of the group of control.

On the other hand, the difference between the groups was very significant ($p < .01$) in favour of the experimental group with regard to the items 5 and 6, including the complex situations. Within the same lines, El Ouidadi *et al.* (2011) noted, during the use of a simulation in the teaching of the cellular division, a progress in the level of acquisition of competences related to the students' cognitive ability of application and their reasoning.

In order to determine if the used simulation made it possible for the students of the experimental group to overcome difficulties of training related to the treated contents, the answers of the pupils to the items were divided into three categories, and they are represented in the following table:

Table 6. Examples of student responses to the post-test

	Correct answer	Partially correct answer	False answer
Question 1: Notch the correct answers?	a- A layer of sedimentary rocks is more recent than that which it recovers. b- Any geological event, which recuts another him is posterior Sedimentation. - To order geological events chronologically.	a- A layer of sedimentary rocks is more recent than that which it recovers. b- Any geological event, which recuts another him is posterior Sedimentation.	a- Give a precise age in million years to a precise rock. b- Any geological event, which recuts another him is former.
Question 2: Compare the age of the layers represented in this figure?	1 (oldest) →2→ 3	1 (oldest) →2→ 3 →2→ 1	3 (oldest) →2→ 1
Question 3: Establish the chronology (older with most recent) of the geological events?	E→D →C→A→ B→ F →G →H	E→D →C→H→ A→ B →G →B	E→F →H→D→ C→ A →G →B
Question 4: Thanks to do a rigorous reasoning, carry out a relative dating of the four events indicated on the document and visible on the geological cut presented?	a- Erosion b- Sedimentation of Limestone and sandstone c- Compression d- Distention	a- Sedimentation of b- Limestone and sandstone b- Compression c- Distention d- Erosion	a- Distension b- Compression c- Sedimentation d- Erosion
Question 5: Identify the chronological order of the geological events observed in the photo?	a- Sedimentation b- Compression c- Erosion d- Sedimentation	a- Sedimentation b- Compression c- Sedimentation	a- Compression b- Sedimentation c- Distension
Question 6: Propose a relative chronology of the geological events observed on the cut of the document?	a- Sedimentation b- Compression c- Erosion d- Sedimentation e- Distention f- Erosion g- Volcanism	a- Sedimentation b- Compression c- Sedimentation d- Distention e- Volcanism	a- Erosion b- Sedimentation c- Compression d- Volcanism e- Distension f- Sedimentation g- Compression

Next, we compared the responses of the students in both groups (see table). The results obtained show that there are no significant differences between the students' responses to questions 1, 2, 3 and 4. However, they do show significant differences between the responses of these students to questions 5 and 6. On the one hand, the rates of correct answers by the pupils in the experimental group are higher than those of the leading group (68.75% compared with 6.25% in the fifth item and 18.75% compared with 0% in the sixth item). On the other hand, the false answers of the pupils in the experimental group are less frequent than those of the leading group (6.25% compared with 12.5% in the fifth item and 25% compared with 37.5% in the sixth item). These results confirm those of the statistical analyses conducted using Mann-Whitney's U test ($p > .01$ for items 1, 2, 3 and 4 compared to $p < .01$ for items 5 and 6).

Table 7. Students' responses to the questions of the post-test.

Questions	Correct answers		Partially correct answers		False answers	
	Control group	Experimental group	Control group	Experimental group	Control group	Experimental group
Question 1	25,00%	18,75%	75,00%	81,25%	0,00%	0,00%
Question 2	81,25%	93,75%	12,5%	6,25%	6,25%	0%
Question 3	18,75%	25,00%	56,25%	50%	25,00%	25,00%
Question 4	12,50%	6,25%	87,50%	87,50%	6,25%	12,50%
Question 5	6,25%	68,75%	81,25%	25%	12,50%	6,25%
Question 6	0%	18,75%	62,50%	56,25%	37,50%	25%

In sum, we noted during the analysis of the students' responses to the post-test that the experimental group demonstrated a better understanding of the relative chronology concept. This was confirmed, on the one hand, by statistically very significant differences ($p < .01$) in favour of the experimental group with regard to items 5 and 6 containing complex situations, and on the other hand, by higher rates of correct answers from pupils in the experimental group, especially for the last two questions.

DISCUSSION

In the present study, it seems that the students of the experimental group, who used the « *chronocoupe* » simulation, have generally managed to implement procedures allowing them to answer questions 5 and 6 more effectively. Students became more able to locate geometric clues on a geological section (question 6) and use them to retrieve the chronology. The post-test responses confirm that these students have also become more capable of identifying the chronology of events on an outcrop photograph (question 5) because their skills, developed as part of the work on a simulated model, are transferred for work on outcrop photography. Similarly, Sanchez (2003), who previously tested this simulation with high school students, reports that learners working independently, when facing such computer environments, are led to adopt a strategy similar to that of the geologist, and as a result, have the ability to trace the geological history of a region by analysing a geological section and a photograph taken in the field.

Thus, it can be inferred that the selected simulation positively impacted the performance of the students in the experimental group and sharpened their understanding (an essential cognitive process for the improvement of application skills) and, consequently, allowed them to overcome certain learning difficulties related to the subject of relative chronology. This result is consistent with the results of several research studies conducted in experimental disciplines which also showed an improvement in learner performance and understanding. For examples, Rutten, Van Joolingen and Van der Veen (2012), who reviewed 51 papers from 2001 to 2010, showed that classical education can be improved by using computer simulations. Similarly, a literature synthesis examines research findings on grade 6–12 student learning gains and losses using virtual laboratories and computer simulation, conducted by Scalise, Timms, Moorjani, Clark, Holtermann and Irvin (2011), indicated that about 53% of the studies (42 articles) reported overall gains, just under 18% (14 articles) reported gains under the right conditions, about 25% (20 articles) reported mixed outcomes in which some groups showed learning gains but others did not, and approximately 4% of the studies (2 articles) reported no gain.

This paper confirms the fact that the integration of a computer simulation (Chronocoupe) in a learning situation concerning relative chronology had a positive effect on student achievement. This result is in good agreement with other studies that have shown that the use of simulations can improve learning outcomes. Indeed, Huppert, Lomask and Lazarowitz (2002) declared that 10th grade biology students who used a computer simulation on the growth curve of microorganisms attained greater achievement on content-based objectives than those in a control group. As well, in the genetic topic, Gelbart, Brill and Yarden (2009) found a significantly positive influence of the computer simulation on learning results. In addition, Gibbons, Evans, Payne, Shah and Griffin (2004) reported the evaluation of computer-based simulation of practical exercises in bioinformatics, and their results indicated that performance can be improved by the use of simulations (by 7%). In another study, Kiboss, Ndirangu and Wekesa (2004) investigated the effectiveness of a Computer-Mediated Simulation (CMS) instruction program in improving secondary school pupils' learning outcomes in cell theory lessons. Their CMS program on the biology subject led to improvements in academic achievement, students' perceptions of the classroom environment

and their attitudes towards the subject. At last, Gambari, Gbodi, Olakanmi and Abalaka (2016) found that the students using a computer simulation performed better, and they recommended that chemistry teachers should use computer simulations for improving their students' performance and motivation in the subject.

Our study proves that simulation used had a positive effect on students' understanding of the experimental group with respect to the subject of relative dating, and this result obtained is broadly consistent with the major trends in the literature as to the effect of computer simulations on students' understanding. Indeed, Torres, Moutinho and Vasconcelos (2015) revealed, in their investigation in the subject of geosciences that the majority of science teachers use simulations to observe phenomena whose observation is inaccessible due to spatial and temporal constraints and to promote a better understanding of the evolution of natural phenomena. Meir, Perry, Stal, Maruca and Klopfer (2005) pointed out that students have deep rooted confusions and misconceptions about how diffusion and osmosis function work, particularly at the molecular level. These researchers revealed that their computer simulation (OsmoBeaker) leads to improved understanding and can help to overcome some students' misconceptions. In the same sense, White and Frederiksen (2000) showed that the use of the computer simulation 'Thinker Tools' in physics enabled secondary school students to demonstrate a better understanding and interpretation of the forces acting on a moving object than higher education students who had received traditional instruction. In addition, Droui, Hajjami, Bouklah and Zouirech (2013) reported positive effects of the use of a simulation of Newtonian laws in a problem-solving context on the conceptual understanding of Newtonian mechanics. Still in the physical sciences, Jimoyiannis and Komis (2001) investigated the role of computer simulations in the development of functional understanding of the concepts of velocity and acceleration in projectile motions. Their results presented that students working with simulations exhibited significantly higher scores in the research tasks. Therefore, the researchers suggest that computer simulations may be used as an alternative instructional tool, in order to facilitate students' understanding of velocity and acceleration and develop functional understanding of physics. On his part, Zacharia (2007), compared a control group only using Real Experimentation (RE) with an experimental group using a combination of RE and Virtual Experimentation (VE). His results indicate that replacing RE with VE during a specific part of the experiment has a positive influence on students' conceptual understanding of electrical circuits. At last, Stern, Barnea and Shauli (2008) compared two groups of students, both of which were taught curriculum on the kinetic molecular theory. The experimental group subsequently spent additional class periods using the computer simulation 'A Journey to the World of Particles'. The students in the experimental group scored significantly higher than the students in the control group on a test measuring their understanding of the theory. However, in the long term these results were negligible.

Furthermore, during the use of the computer simulation by the experimental group, we observed a strong motivation among the pupils who communicated and interacted increasingly with one-another. This result is supported by those of Durán, Gallardo, Toral, Martinez-Torres and Barrero (2007) who focused on both the cognitive and affective domains in order to investigate the effects of a computer simulation on students' motivation, interaction and participation. Researchers replaced part of the traditional method in a subject titled 'Electrical Machines and Installations' with a software-based method that made use of a computer simulation. While the results for the cognitive domain could not be clearly interpreted, the results for the affective domain indicate that a synchronous software-based active methodology promotes discussion both among students and with the teacher in a brainstorming. In addition, the proposed methodology improves participation and students' initiative compared to traditional instruction.

However, other studies have reported less impressive results in using computer simulations in science education. Some of these have found no advantage to utilising simulations over traditional methods. For example, Thomas and Hooper (1991) state that in some situations the contribution of simulations is uncertain or even null. Winn, Walker, Greene and Mansell (2006) compared college undergraduates' achievement of oceanography concepts through field and simulated experiences. Results showed that there was no difference in overall learning between the fieldwork and simulation groups. Other investigations have indicated the use of computer simulations to be less effective than traditional instruction and hands-on laboratory approaches (Rieber, 1990; Michael, 2001; Marshall, *et al.*, 2006). Even more, Clark (1994) declared that improvements in student achievement are more attributed to effective instructional methods and teacher effects. In the same sense, Trundle and Bell (2010) reported: «Simply providing opportunities for students to use computer simulations without careful attention to learn support and instructional models is not likely to result in desired instructional outcomes». Thus, despite the high potentials for simulations, a general conclusion about their effectiveness is currently unwarranted (Yaman *et al.*, 2008).

In the end, even though research tasks concerning the place of ICT in the teaching of earth sciences are still largely missing (Durbin, 2002; Gobert *et al.* 2002; Kali 2003; Linn 2003), they all underline the interest, which such means can offer to help students to represent complex phenomena, three-dimensional structures and space relations between geological objects. (Lefèvre *et al.*, 2006). Consequently, the teacher can be required to suggest computerised models in the form of animations or of simulations (Sanchez, 2008). These later give the opportunity to observe a scale model or accelerated geological events, which are not accessible to the direct observation for different reasons such as time (for example very low speed of certain geological phenomena) or space (gigantic or microscopic dimensions of certain geological objects).

CONCLUSION

In this study, the aim is to highlight the impact that numerical simulation has on learning in the fields of relative chronology. Statistical data collected from a semi-experimental research which was conducted among students in a technical high school in the city of Taza (Morocco) using the pre-test and post-test methodology with an experimental group and a control group showed that there was no significant difference between the two groups during the pre-test [$t(30) = -0.414$, $p = 0.682$]. After completion of the proposed pedagogical activity, there was a statistically significant difference between the experimental group and the control group [$t(30) = -0.414$, $p < 0.05$] on the post-test. The pedagogical application used in this study obviously improved the results of the students of the experimental group, which confirms the fact that the integration of a digital simulation (Chronocoupe) in a learning situation concerning relative chronology certainly had a positive effect on student achievement.

On the other hand, the results obtained during the post-test, which was based on Mann-Whitney's U test, confirm that the difference between the groups was very significant ($p < .01$) in favour of the experimental group in regards to items 5 and 6, which included complex applications. Thus, it can be inferred that simulation used had a positive effect on the boosting of students' understanding of the experimental group with respect to the subject of relative dating, and thus allowed the students to overcome certain learning difficulties related to the concept of relative chronology.

No significant differences were noticed with regard to the other questions (1, 2, 3 and 4), which targeted knowledge acquisition and application in simple situations. This has been

confirmed by Mann-Whitney's U test, which shows some limitations of the application utilised. Nevertheless, during the exploitation of the computer simulation by the experimental group, we noticed a strong motivation among the pupils who communicated and interacted increasingly with one-another. This concerned a discipline that is widely under-appreciated by the pupils (Gohau, 2001, Dodick *et al.*, 2003).

Numerous benefits for the use of simulations were cited by authors: higher learning gains, better conceptual understanding, decreased study time, higher student satisfaction and more participation (Smetana *et al.*, 2012; Rutten *et al.*, 2012). However, according to other researchers, learning outcomes appear to be improved when computer simulations are used in conjunction with other representations and modes of instruction (Zacharia, 2003). Indeed, in the present study, computer simulation has been used in PBL to reinforce cognitive skills by encouraging students to be more active and autonomous.

Thus, we believe that an effective and educational simulation, provided that it is appropriately implemented at the right moment, can contribute effectively to resolving certain learning problems in the field of Earth sciences. But this implies the existence of quality numerical simulations that are appropriate and adapted to the school programs.

Finally, although these findings may seem a relevant contribution to research on the use of numerical simulations, it should be noted that they are based on a single computer simulation, in a particular context, dealing with a narrowly targeted subject. The results of this work need to be confirmed in other contexts, with other simulations and for other disciplinary fields.

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APPENDIX

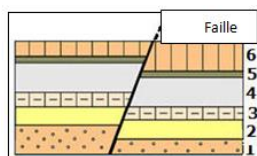
a) Appendix 1: Pre-test

Question 1: Notch the correct answer?

- The relative dating is a dating leading to a quantified result, expressed in years.

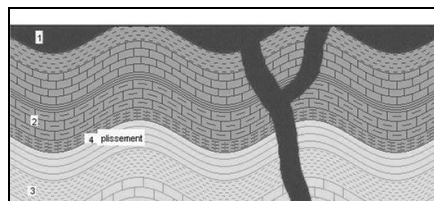
- ☐ True
☐ False

Question 2:



- To compare the age of the layers represented and to order the geological events?

Question 3:



- Propose a relative chronology of the geological events observed on the cut of the document

Question 4:

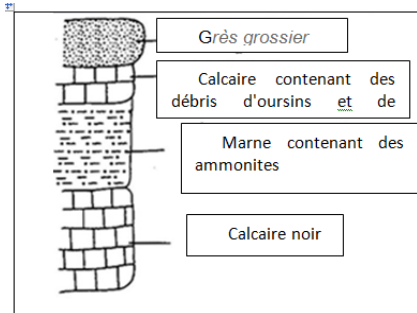
The document presents the geographical and chronological distribution of two fossils found in the layers of Ouled-Abdoun:

Fossil B (Notidanus)	Fossil A (Corax)	Geographical distribution	
+++++	+++++	Cenomanien	Chronological distribution
		Turonien	
		Senonien	
		Messinien	
		Maastrichtien	
		Thaetien	
		Ypresian	
		Lutetien	
+			
+			
+			
+			
+			
	+		

- a-Compare the geographical and chronological distribution of the two fossils.
b-what are the considerations about the stratigraphic interest of the fossils compared?

Question 5:

By using the furnished information in the document below:



- Compare the age of the rocks represented in the document? Which is the principle which you adopted?
- Determine the age of the Marl? Justify your answer?

b) Appendix 2: Post-test

Question 1:

Notch the correct answers?

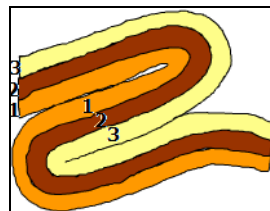
a- The principle of superposition it is:

- ☐ A layer of sedimentary rocks is more recent than that which it recovers.
- ☐ A layer of sedimentary rocks is older than that which it recovers.
- ☐ Give a precise age in million years to a precise rock.

b- The principle of stepping, it is:

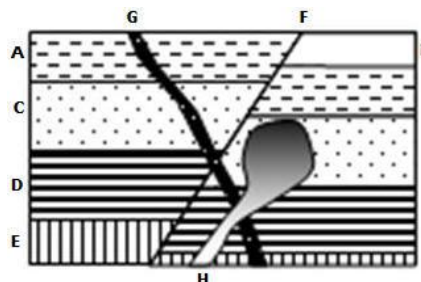
- ☐ Any geological event, which recuts another him is posterior.
- ☐ Any geological event, which recuts another him is former.
- ☐ To order geological events chronologically.

Question 2:



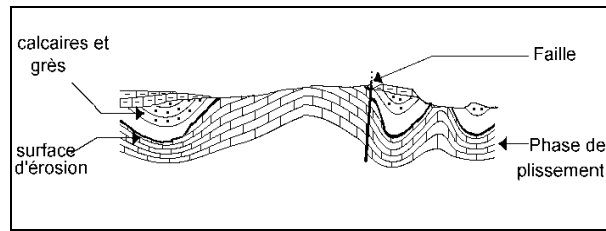
- Compare the age of the layers represented in this figure?

Question 3:



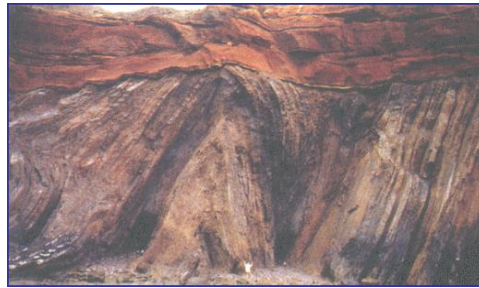
- Establish the chronology (from the old to the recent) of the geological events?

Question 4:



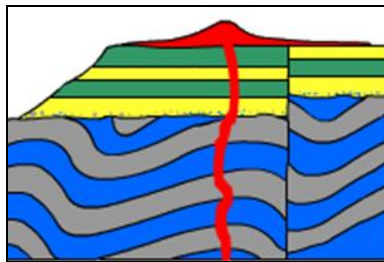
- Thanks to do a rigorous reasoning, carry out a relative dating of the four events indicated on the document and visible on the geological cut presented?

Question 5:




- Order chronologically (older with most recent) of the geological events observed on the photograph?

Question 6:



- Propose a relative chronology of the geological events observed on the cut of the document?

Grid Analysis Display System (GrADS) and Multi Modus Visualization in Earth Science Learning Mastery and Spiritual Aspect to Enhance Concept

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ABSTRACT

The aim of this study was to enhance the student's concept mastery and embedded spiritual attitude in the learning of earth science with the help of visualizations and authentic data analysis using GrADS. 23 pre-service physics teachers in Bengkulu, Indonesia participated in this study. This study used mixed methods with embedded experiment design. Multiple choice questions were used to collect the concept mastery data; questionnaires and open ended questions were used to collect data about spirituality attitude. The students' testimonials about the learning program were explored by using open ended questions. The multiple choice questions were analyzed quantitatively while the observation, questionnaire, and open ended questions were analyzed qualitatively. The results show that the students' concept mastery improve from no mastery to mastery with the average N-gain being 0.8 (high). The students got implicit values that had an impact on their spirituality of awareness and belief in the divinity of God. Similar research about embedding the spiritual aspect in the learning of earth science has not been reported widely

Keywords: concept mastery, spiritual aspect, earth science, visualization, GrADS

INTRODUCTION

Almost all of earth and space science (ESS) concept is imaginary. Most of them cannot be observed directly, (Sunderlin 2009). There is a very high potential to make students feel it is difficult to understand the concept correctly. Character concept that is related to directly unobservable phenomena cause an alternative concept or naïve concept among students (Miller & Brewer, 2010; Jolley, Lane, Kennedy, Seneclauze, & Frappe, 2012). That appears different to alternative conceptions besides scientific conceptions (Joley, 2012; Miller, 2010). Media visuals can be a solution to help visualize the abstract concept. Various



media visuals can be used to explain the earth concept. An animation is a potential media to visualize the concept of the earth's atmosphere that otherwise could not be observed directly. Animation is a sample of using technology in a learning activity (Bezen, Aykutlu, and Bayrak, 2016). Phenomenon that happen in nature can be understood, observed, and interpreted through the help of technology. A learning activity using technological resources help students to get a complete understanding (Santos, 2016).

Although media visualization had been used widely in learning, there is still a need to encourage its use, especially in Bengkulu, Indonesia, and especially in ESS. Smith and Bermea (2012) investigated the alternative conceptions about plate tectonics using visualization from students' sketches in a learning activity. Sibley (2009) used scientific model as visualization to analogize a concept to help the student's to understand the concept well. In addition, collaboration science research and learning research is just a recent trend in education study. The result of science research is used to facilitate the student's thinking process. Visualization in earth science learning can support the student to improve their concept mastery. According to Bloom, concept mastery is the ability to understand the material of learning comprehensively, be able to provide interpretation, and be able to apply it (Anderson, 2001).

Based on a study case whose purpose was to investigate the student's conception about the phases of the moon in the University of Bengkulu, it was known that most of the respondents had naïve concept. 45 pre-service physics teacher students in Bengkulu, Indonesia participated in the study case. 1 respondent had alternative conceptions, and 2 students had incomplete conceptions. None of them showed any scientific conception. The criteria of conception followed the criteria of Park (2013). Student alternative concept can be seen at Figure 1.

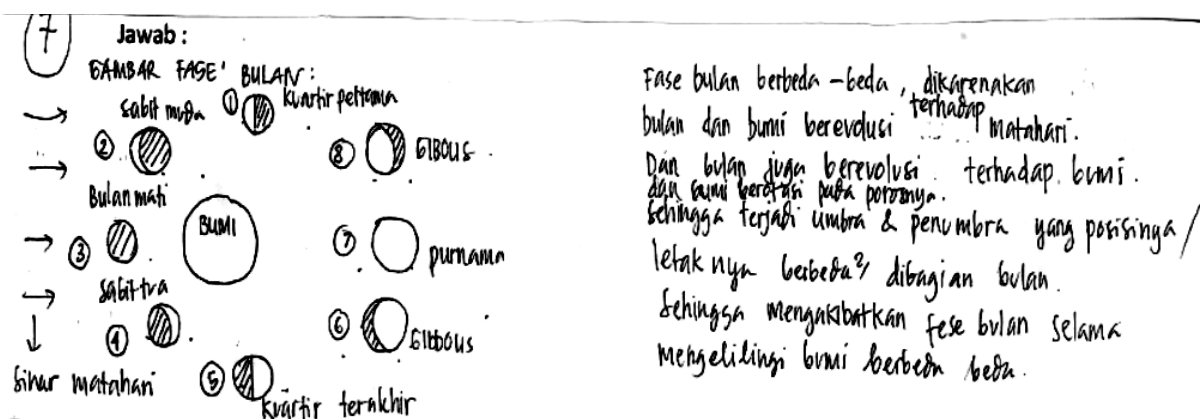


Figure 1. Students' alternative concept of the phases of the moon

Figure 1 shows that the student could not explain that the total amount of sun rays that reaches the moon's surface is constant. The student assumes that the total amount of sun rays that reaches the moon's surface is different in each phase of the moon. The student understands that the phases of the moon are caused by the umbra and penumbra, similar to the eclipse of the moon. This result indicated that the student's mastery of especially earth and space concept still needs to be improved. Johan (2014) reported that the improvement of concept mastery after implementation was only with an N-gain of 0.49 in category moderate. That study used the learning model search, solve, create and share (SSCS) problem solving in the University of Bengkulu. Werts and Hinnov (2011) present visualization in the form of a three dimension graph from authentic data that was analyzed by Matlab. Ellwein (2014), and was concerned with developing a module based data to facilitate the learning of students who

have never worked with authentic scientific data. This study provides an ESS learning program using multi modus visualization such animation, picture, and graph to enhance concept mastery. The GrADS software is easier to operate for the simple analysis of geoscience data. The research science was harnessed to enable the student to understand the concept, and provided a different learning process. These results indicate that the concept mastery of college students in Bengkulu still must be focused especially on earth and space concept. Media visuals can visualize every step of the process in nature phenomena related to the ESS concept. An authentic data analysis using GrADS is expected to help to strengthen and help the student's proper understanding of the concept.

Unayah and Sabarisman (2015) publicized that about 60% of adolescents were involved in crime. The Central Bureau of Statistics of Indonesia (2010) documented that more than 60% of adolescents participated in theft and more than 9.5% of them were involved in drugs. Reza (2013) stated that the increase in cases was caused by the decline in the moral values of teenagers in Indonesia. The religious aspect of learning ESS can influence the morality of a teenager. The spiritual aspect has an important value as it can block the degradation of morality. The spiritual aspect increased also our awareness of God Almighty (Muthohar, 2013). In addition, the decline of moral values among teenagers in Indonesia is very worrying. The axiology side of learning ESS are to understand the phenomena of nature well, to appreciate nature and to behave responsibly in nature, to be able to perform actions in disaster mitigation appropriately, to exploit nature wisely, and to increase the awareness of the existence and greatness of God Almighty. A common description of the Indonesian National Qualification Framework (INQF) stated that the implementation of the national education system and work training systems, which were done in Indonesia at every level qualification, included the processes that cultivate affection, one of which is the fear of God Almighty. The INQF general description can be the basis for developing learning programs in higher education. In the ministerial regulations appendix No. 49 of 2014, it was also stated that every graduate from an academic, a vocational, and a professional education program must have good moral attitudes, including the fear of God Almighty and be able to demonstrate a religious attitude. Integrating a spiritual value in the learning of science is expected to contribute to blocking moral degradation and is expected to be the solution for the demands of the INQF in relation to the religious aspect.

Concept mastery is an important aspect of learning. Earth and space science (ESS) concept is related to phenomena that are unobservable directly so it needs media visuals to help visualize it. Media visuals can help students to understand the concept more comprehensively. Earth and space science (ESS) is related to nature phenomena. In order to understand fully the ESS concept there is the need for research based material (RBM) related to geoscience research that can help display the real condition of nature, especially in Indonesia. Authentic data of geoscience can be analyzed using the Grid Analysis and Display System (GrADS) to display the real condition of Indonesia. The result of the GrADS can be harnessed as a RBM in learning earth science. This study provided a learning of the earth that focused on improving the student's concept mastery with the help of media visuals and with the help of authentic data analyzed using GrADS. Based on the research background, this study provided earth science learning using media visuals to enhance concept mastery and to embed a spiritual attitude. Research questions included how to enhance the student's concept mastery with the help of media visuals and with the help of authentic data analyzed using GrADS and how to embed a spiritual attitude through the learning of earth science. Authentic data analyzed using GrADS was used to strengthen the students' concept mastery. The embedding of the spiritual aspect was done by exploring the value of the earth's atmosphere concepts. The embedding of the spiritual aspect of learning natural science, especially ESS, had not been reported widely. The novelty of this study is the harnessing of multi modus

visualization, compilation research science from analysing authentic atmosphere data using GrADS in learning, and integrating the spiritual value of ESS.

The aim of this study is to enhance concept mastery and to embed a spiritual attitude in the learning of earth science with the help of media visualization and the analysis of authentic data using the GrADS.

METHODS

Research Design

This study used the mixed methods research design with embedded experiment design. A mixed methods research is a method of collecting data and analyzing data by combining the qualitative and quantitative approach used together in one study. One type of mixed methods research is embedded experiment design. Embedded experiment design can use pre experiment, true experiment, or quasi experiment design at its intervention step (Creswell and Clark, 2007). The mixed methods research design with embedded experiment design was selected in this study because before the intervention step we needed to develop a learning process in order to enhance the student's concept mastery and to embed a spiritual attitude. In the intervention step (pre experimental design was used), it needed the quantitative data to measure the enhancement of the student's concept mastery and the shifting of the student's spiritual attitude and at the same time we needed the qualitative data to get a description of how the learning process could enhance the student's concept mastery and effect of the student's spiritual attitude. This article focuses on the result of the intervention step related to the enhancement of the student's concept mastery and the shifting of the student's spiritual attitude.

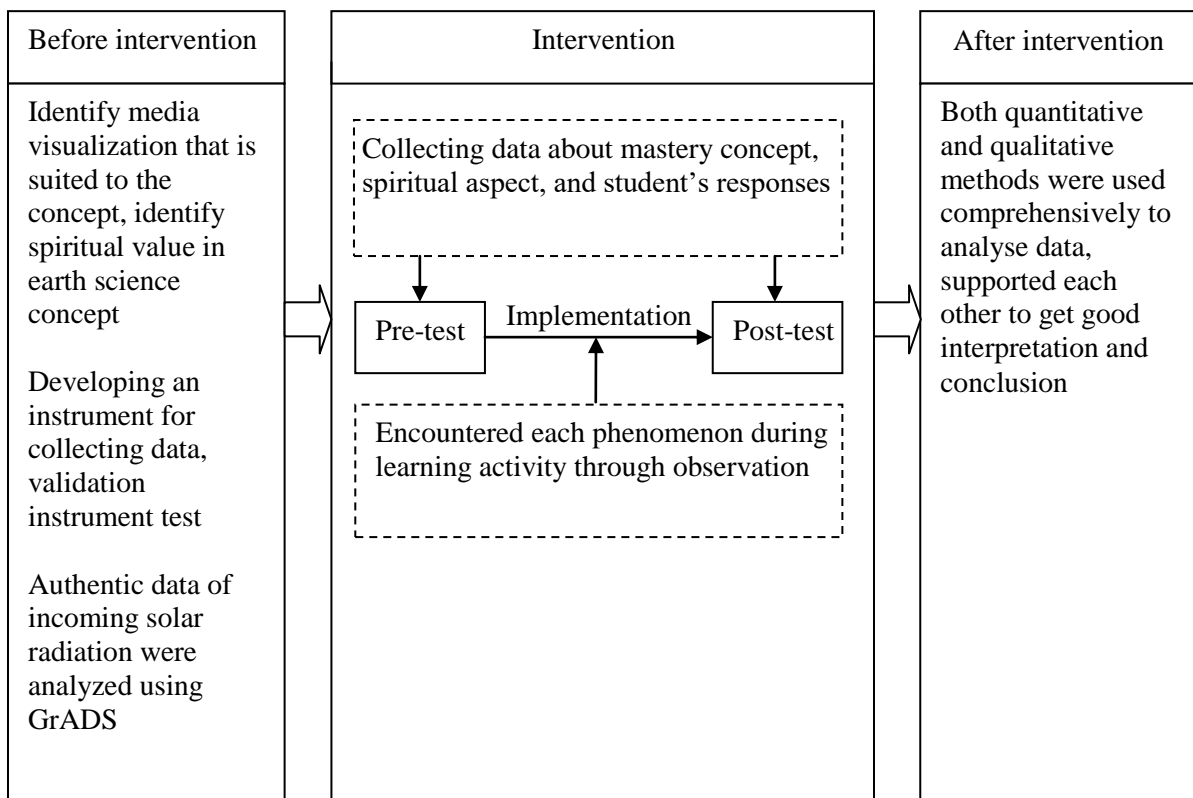


Figure 2. Embedded Experiment Design (Creswell and Clark, 2007)

The embedded experiment design in this study included three steps: before intervention, intervention, and after intervention. The before intervention step included developing media visualization, analyzing authentic data, developing an instrument, and designing learning activities. Interactive Conceptual with Chain Till Unanswered Questions (IC-CTUQ) was designed in this step. Interactive conceptual learning included four parts. They were concept focus, using text, interactive classroom, and RBM. The RBM came from science research which analyzed authentic data using GrADS. Concepts were explored to embed a spiritual aspect. Spiritual attitude in this study was belief in the nature of divinity. The nature of divinity in this study were God is the infinite creator, God is the infinite gracious, God is the infinite assign, God is the almighty, God is the infinite nurture, and God is the infinite wills. In this article, the before intervention step, including developing media visualization, analysis authentic data, developing instrument, and designing learning activities is not the focus of the discussion.

In the intervention step, earth learning using interactive conceptual with chain till unanswered question using visualization was implemented on 23 pre-service physics teacher students in Bengkulu, Indonesia. This step was used in the one group pre-test and post-test design. Both quantitative and qualitative data were collected in this step. The implementation learning program used the one group pre-test post-test design. In the learning activities of the IC-CTUQ model, multi modus visualizations were used in the concept focus steps. The students were engaged to construct the concept interactively with the help of visualization. The visualization used in this study included figure, animation, and graph. The visualization came also from the analysis of authentic data. Media visuals were used to visualize unobservable concepts to facilitate the students' understanding easily. Questions and feedback were done along the learning activity. Media visualization, questions, and feedback were used to present spiritual values for embedding the spiritual aspect. The students were given questions to explore the value in natural phenomena. The use of text step helped the students to find key words about the concept which was presented by media visualization. In the RBM step, the students were engaged to interpret visualization about the real condition of Indonesia. The students were engaged to find the correlation among concepts using real visualization from GrADS about the real condition of the earth especially in Indonesia. The last step was the analysis and the conclusion. In this step, both the quantitative and qualitative methods were used to analyze data comprehensively; the quantitative and qualitative methods supported each other to get a good interpretation and to reach a conclusion.

Subject in This Study

To conduct this study, a group included people who knew each other. 23 pre-service physics teacher students who are taking the ESS course during a semester of the 2015–2016 academic year were involved in this study. Convenience sampling was used in this study. The characteristics of the subjects in this study can be seen in Table 1.

Table 1. *Characteristic study's subject*

Gender	Quantity	Range of age
Male	9 person	18–19 years old
Female	14 person	

Instrument for Collecting The Data

Three instruments were developed to collect data quantitative and data qualitative. The quantitative data were collected by conducting a multiple choice test (for the data of the

enhancement of concept mastery) and questionnaire (for the data of embedding spiritual attitude) while the qualitative data were collected by open ended questions (for the data of embedding spiritual attitude), student's testimonials (to collect the students' responses to the learning process). Both the student's testimonials and open ended question were used to support the quantitative data (concept mastery and spiritual attitude). A sample of a question in the multiple choice questions can be seen in Figure 3.

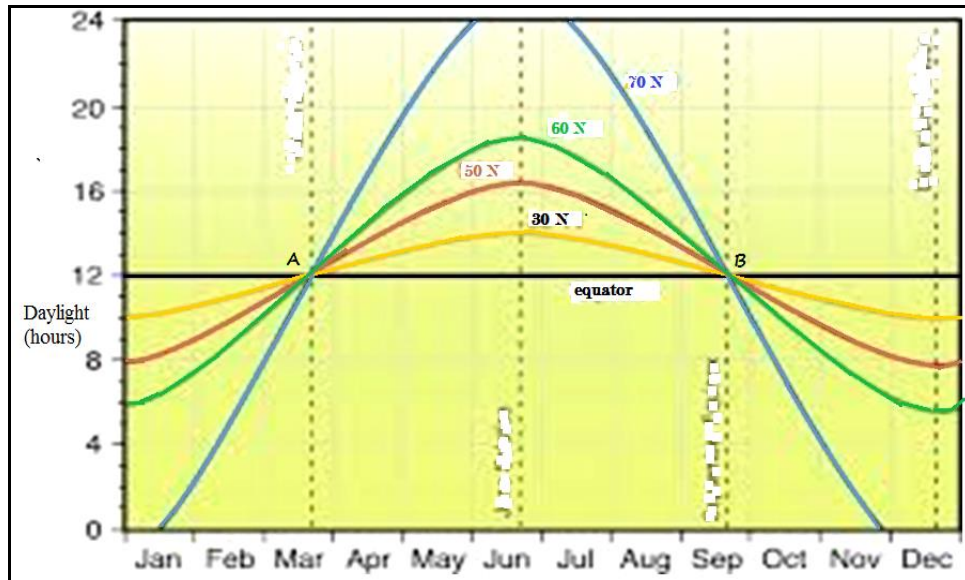


Figure 3. Graph of length of daylight

Look carefully at the graph. Based on the graph above, how is the difference in the solar position in March, June, and December?

- Perpendicular at 23,5o Northern Hemisphere, perpendicular at 23,5o Southern Hemisphere, and perpendicular at equator.
- Perpendicular at 23,5o Southern Hemisphere, perpendicular at equator, and Perpendicular at 23,5o Northern Hemisphere.
- Perpendicular at 23,5o Northern Hemisphere, perpendicular at equator, and perpendicular at 23,5o Southern Hemisphere.
- Perpendicular at equator, perpendicular at 23,5o Southern Hemisphere, and Perpendicular at 23,5o Northern Hemisphere.
- Perpendicular at equator, perpendicular at 23,5o Northern Hemisphere, and perpendicular at 23,5o Southern Hemisphere.

To answer the question, the student must pay full attention to the graph and must be understand to correlated concept length of daylight in graph and concept incoming solar radiation of the annual solar motion.

The students' spiritual attitude was obtained by the questionnaire. The data from the questionnaire was supported by the qualitative data from the open ended questions. The questionnaire used in this study can be seen in Table 2. The questionnaire was given at the pre-test and post-test stage. The open ended question was given in post-test stage only. The open ended question includes 6 questions. A sample of the open ended question can be seen below:

“After learning activities, how can you explain that the concepts of earth science and learning process make you believe more that God is the infinite assign?”

Table 2. *Questionnaire for spiritual aspect*

No	Spirituality Aspect	Response									
		No			→				yes		
		1	2	3	4	5	6	7	8	9	10
1	I realize that God is the infinite creator										
2	I realize that God is the infinite gracious										
3	I realize that God is the infinite assign										
4	I realize that God is the almighty										
5	I realize that God is the infinite nurture										
6	I realize that God is the infinite wills										
Total response (%)											

Students' testimonial about learning program was explored by using open ended questions. For example, the open ended question was to collect the students' testimonials about how visualization in the learning process could help them understand a concept clearly and easily. Both the data for concept mastery and the spiritual attitude were supported by the qualitative data of the testimonial and the observation sheet during the learning activity. These instruments were validated by three experts. Logical validity for these instruments included the verification of three aspects: formulation of indicators, key answer, and editorial. The experts confirmed that the instruments were valid and worthy to use in this study. A set of multiple choices used to collect data of concept mastery was tested to obtain the reliability value. 34 pre-service physics teachers were involved. The validity value obtained was in range 0.45 (category moderate) - 0.74 (category high). The test retest method was conducted to get the score of reliability. The distance between the first test and the second test was two weeks. The reliability score of 0.83 obtained in the category was very high.

Learning Activities

The Learning Model Interactive Conceptual with Chain till Unanswered Questions (IC-CUQ) using visualization was developed to enhance conceptual understanding and to embed a spiritual attitude. This learning model included five parts: concept focus, using text, RBM, class room interaction, and chain till unanswered questions. The chain till unanswered questions at the end of the learning process was focused on embedding spiritual attitude. Before the intervention step, this learning model was tested on 15 pre-service physics teacher students in Bengkulu, Indonesia. The result indicated that this learning model, the IC-CUQ, using visualizations could enhance the students' understanding of concept and embed a spiritual aspect. In the intervention step, this learning model IC-CUQ using visualizations was implemented to know whether there has been a shift in the students' mastery and their spiritual attitude. The design of the learning activities in this study followed the learning model in Table 3.

Table 3. *Learning model Interactive Conceptual with Chain till Unanswered Questions (IC-CUQ) using visualization*

<p>Concept focus</p> <p>Visualizations are used to represent the concept, to help the student understand a concept. Concepts are explored to embed an attitude of belief in the disposition of God. In this section, visualization such as animations was used to help embed a spiritual attitude, spiritual value inserted in nature phenomena.</p> <p>For example, students were given an animation about the annual movement of the sun and a graph of the sun’s position during a year. Questions and feedback were used to engage the student to construct their concept actively.</p> <p>An example is for embedding the spiritual aspect, a spiritual value was inserted in the earth rotation concept. The revolution of the earth causes a change of seasons. It balances the condition of the earth so human life and every life on earth can feel comfortable. It becomes very unbalanced if there is just one season (just winter or just summer). It shows that God is infinite creator and infinite gracious</p>	<p>Classroom interaction</p> <p>Discussions are done during the learning activity.</p>
<p>Use of text</p> <p>Literature books and hand outs are used to find the key word about the concept that was visualized. Handout were designed also to embed the spiritual aspect. The spiritual values about the dispositions of God in nature phenomena are inserted in the hand out. The hand out also has pictures as a visualization of concept. The students discuss the key word of the concept using the text (handbook and hand out)</p>	
<p>Research based material :</p> <p>Science research, which analyses authentic data using GrADS (Grid Analysis and Display System) are harnessed to help students understand the concept easier and also clearly. The students were encouraged to interpret the visualization from the GrADS analysis, correlated it to the earth concept that they learned.</p>	
<p>Chain till Unanswered Questions</p> <p>A series of questions related to a natural phenomenon was given until the question could not be answered scientifically and returned to the statement of God is almighty</p>	

Analysis data

The multiple choice questions and the questionnaire were analyzed quantitatively while the open ended questions, student's testimonial, and observation sheet were analyzed qualitatively. The students' testimonial related to the spiritual aspect and the students' responses for the learning activities were coded to find the pattern of the responses. Both quantitative and qualitative approach were used comprehensively to analyze the data supported each other to get a good interpretation and to reach conclusion. For calculating the enhancement of concept mastery, normalized gain was used. The enhancement of concepts mastery was analyzed by the difference between pre-test and post-test score and then was calculated. The enhancement of the level of mastery for each concept in the earth's atmosphere was analyzed also. The formula to calculate the normalized gain score <g> of enhancement of concepts mastery can be seen below.

$$\langle g \rangle = \frac{\langle S_{post} \rangle - \langle S_{pre} \rangle}{S_{max} - \langle S_{pre} \rangle}$$

S_{post} is post-test score, S_{pre} is pre-test score, S_{max} is maximum score, and $\langle g \rangle$ is normalized gain average score (Meltzer, 2002).

FINDINGS

Concept Mastery

The data for the concept mastery were collected at the pre-test and post-test stage. After the learning process, the concept mastery shifted as shown in Table 4.

Table 4. *Mastery shifted in each concept*

Concept	Pre-test	Post-test	$\langle g \rangle$	Category
earth revolution	39%	100%	1	high
solar eclipse	35%	100%	0.94	high
moon phase	52%	96%	0.83	high
annual solar movement	35%	98%	0.89	high
moon eclipse	4%	35%	0.32	moderate
incoming solar radiation	48%	96%	0.85	high
Average			0.8	high

Concept mastery in this study followed the taxonomy bloom revision (Anderson, 2001). Table 4 indicates the concept mastery shifted from no competence to mastery with the category of improvement being high. The improvement in the student's concept mastery was calculated from the pre-test and post-test score. The N-gain distribution for the concepts mastery can be seen in Table 5 below.

Table 5. *$\langle g \rangle$ distribution for concepts mastery*

N-Gain	Category	Total
$g > 0,7$	High	87%
$0,3 \leq g \leq 0,7$	Moderate	13%
$g < 0,3$	Low	none

Category $\langle g \rangle$ in Table 5 shows that most of the student's concepts mastery improvement was mostly in the category high. The distribution of the N-gain/ $\langle g \rangle$ in each category indicates that the learning activity had a good impact on the improvement in the student's concepts mastery. No one stayed at category low. The average of the student's $\langle g \rangle$ score is 0.8 (category high) $\langle g \rangle$ in this study can be seen in Figure 4.

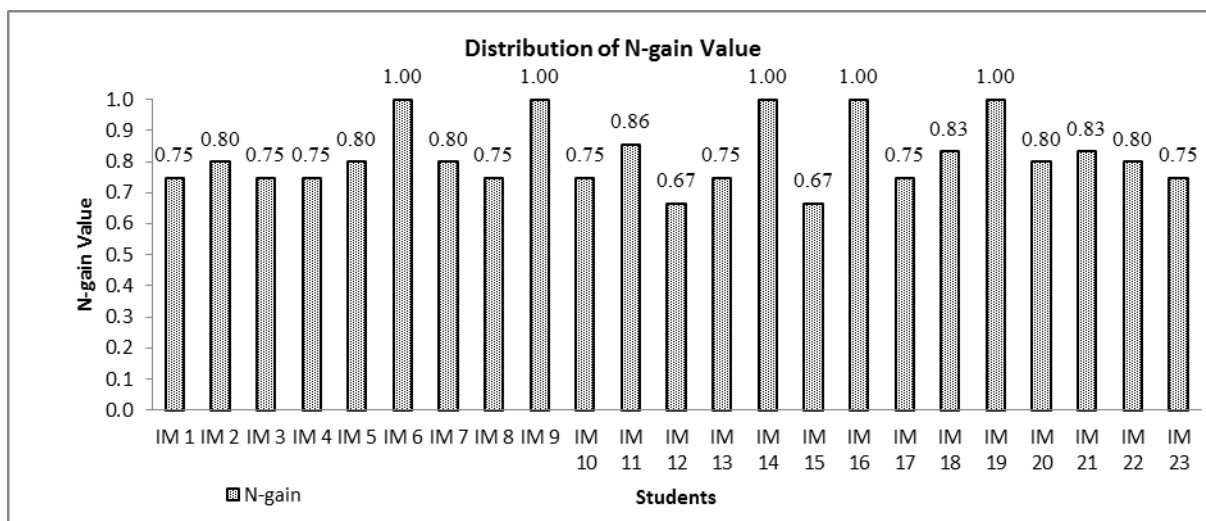


Figure 4. N-gain of each student

Spiritual aspect

The data for spiritual attitudes were obtained by questionnaire and open ended questions. The students' spiritual attitude in this study can be seen in Table 6.

Table 6. *The shifting of students' spiritual*

No	Spirituality Aspect	Before implementation					After implementation				
		No → Yes					No → Yes				
		1	...	8	9	10	1	...	8	9	10
1	I realize that God is the infinite creator	0	0	0	0	23	0	0	0	0	23
2	I realize that God is the infinite gracious	0	0	1	1	21	0	0	0	0	23
3	I realize that God is the infinite assign	0	0	1	2	20	0	0	0	1	22
4	I realize that God is the almighty	0	0	1	1	21	0	0	0	0	23
5	I realize that God is the infinite nurture	0	0	2	1	20	0	0	0	2	21
6	I realize that God is the infinite wills	0	0	1	1	21	0	0	0	0	23
Total (%)		0	0	4.4	4.4	87.5	0	0	0	2.1	97.8

Table 7. *Result of analysis spiritual aspect from open ended question*

No	Student's evidence related to process of embedding spiritual
1	Spiritual values were revealed when earth and science concepts were presented along the learning activity.
2	The harmony, complexity, and precision everything in nature that was presented during the learning process improved the students' total awareness of a mighty God.
3	Unanswered questions in chain questions made students aware about human finitude.
4	Media visuals especially animation could present detail of unobservable phenomena.

Based on Table 6 above, the students' spiritual attitude shifted between before and after the implementation of the learning program. Before the learning process, the students' spiritual attitude had been good. The result of the analysis of the spiritual aspect from the open ended question is showed in Table 7.

Authentic data analyzed

The result from the analysis of the authentic data using GrADS is also an important finding in this study. Authentic data of the incoming Surface Net Solar Radiation on Indonesian atmosphere during 1990 and 2010 were analyzed. A sample of the result of the authentic data analysis can be seen in Figure 5.

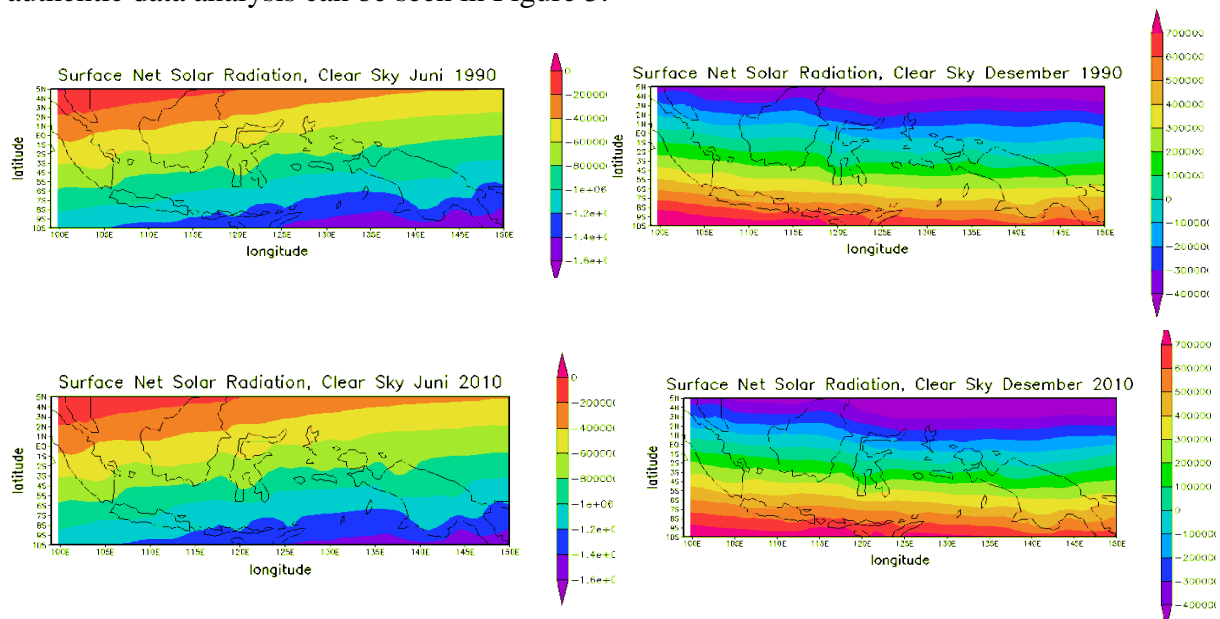


Figure 5. Sample of surface solar radiation at atmosphere in Indonesia in 1990 and 2010

The red colour was interpreted as surplus solar radiation than the blue one. In June 1990 and 2010, northern of Indonesia had surplus solar radiation. It is opposite to the southern Indonesia. It indicates that the intensity of solar radiation in northern Indonesia is greater than at the equator and in southern Indonesia. In December 1990 and 2010, it is opposite with June. Solar radiation in southern of Indonesia is greater than at the equator and northern Indonesia. Figure 5 can support the understanding of the concept such as incoming solar radiation (insolasi), earth revolution, and annual solar movement. In addition, these concepts used visualization also (animation and figure) to facilitate the students' understanding of these concepts.

DISCUSSION

Concept mastery

Based on the findings in Table 6, the improvement of mastery for concept is very satisfactory with an average $\langle g \rangle$ score of 0.8 (category high). Allegedly, the improvement of the student's concept mastery was influenced by visualization in the learning activity. Visualization included animation, figure, graph, and display from authentic data analysis. Multi modus visualizations used in the learning activities provided a chance to engage the students to construct concepts, correlate concepts, and also facilitated them to thinking

causality. Presseisen in Costa (1988) reveals that one of type of thinking skill is correlation including partial thinking skill and totality, pattern, analysis and synthesis, sequences and logical deduction. An example of visualization used in the learning activities can be seen in Figure 6.

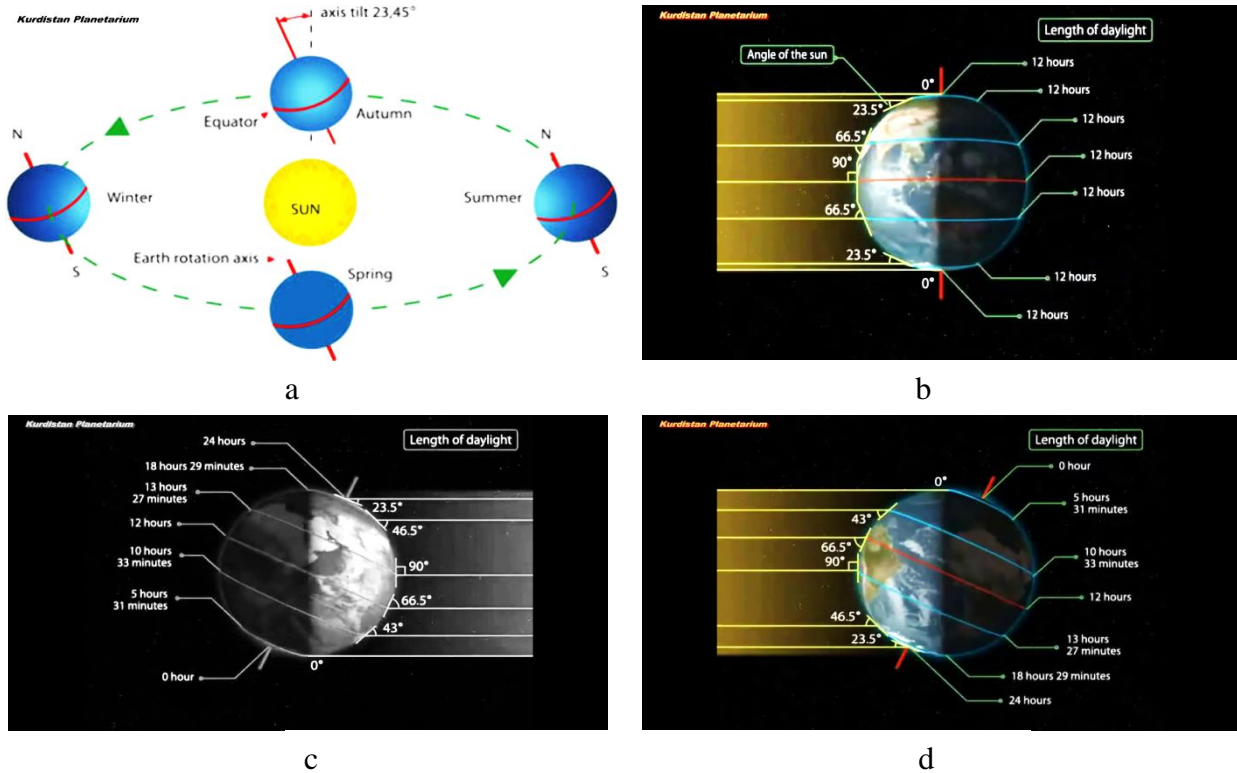


Figure 6. Capture from an animation used in learning activities, a. earth revolution during a year; b. equinox; c. summer solstice; d. winter solstice (source: Kurdistan planetarium)

Figure 6 is captured from an animation that showed the earth's revolution process during a year. The students were encouraged to discuss the concept of earth's revolution, incoming solar radiation, and annual solar movement based on the animation. Animation in Figure 5a visualized the earth's revolution completely while the animation in Figure 5b, 5c, 5d visualized the equinox, summer solstice, and winter solstice as part of earth revolution. Media visualizations succeeded in helping the student improve their reasoning and concept mastery on ESS (Johan, Suhandi, and Wulan 2016, Johan, Suhandi, and Wulan 2017a). Visualization can explain the correlation among various variables (Werts and Hinnov 2011). The demonstration, which involved a seminar and exhibitions of models, videos, posters, and a graph display the growth in atmospheric CO₂ and total temperature, looks to have had an impact on the pre-service teachers' understandings and mindfulness about environmental (Saribaş, Küçük, and Ertepinar, 2016). Drawing or diagrams could represent students' conceptions about the nature of science (Colagrande, Martorano, and Arroio, 2016).

Figure 6b, 6c, and 6d showed different angles of the sun during the equinox, summer solstice, and winter solstice during the annual movement of the sun. A difference in the angle of the sun influences the intensity of the incoming solar radiation to the earth's surface. The media visuals in Figure 6 are supported by Figure 7.

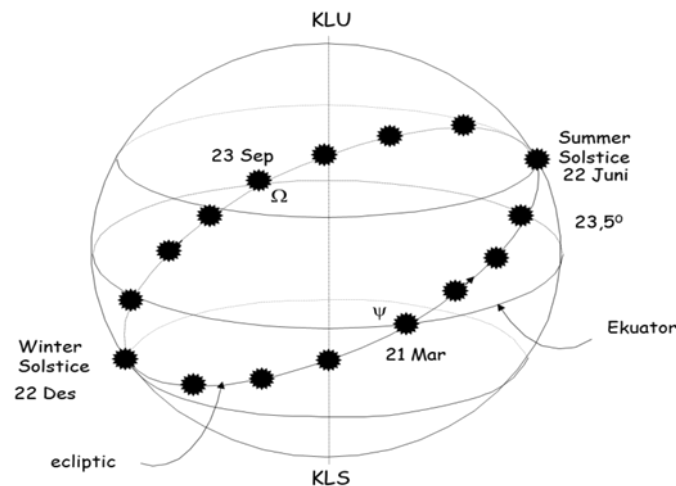


Figure 7. Diagram of annual solar movement

Figure 7 above visualizes the position of the sun's motion. It shows the position of the sun during the summer solstice and winter solstice. In this study, multi modus visualizations are explored maximally to help the students to construct and understand the concept well. Visualization that was used to support each other facilitated the student's correlation of the concept. This is supported by qualitative data from the student's testimonial that gives evidence that animation helps them to understand the concept easier. A sample of the student's testimonial is available in Figure 8 (a) and (b).

Media visualisasi yang ditampilkan dalam pembelajaran IPA sangat bagus, gambar, animasi, bagan / grafik yang ditampilkan sangat jelas dan mudah dipahami, sehingga sangat membantu kami untuk mempermudah memahami konsep yang disampaikan.

(a)

Kebermanfaatan media bagi saya membantu dalam proses belajar dan memahami konsep dan bisa membayangkan seolah-olah benar-benar terjadi

(b)

Figure 8 (a) and (b). Sample of the student's testimonial related to the aids of media visuals in the learning process

The student's testimonial in Figure 8 (a) provides evidence that "Media visuals used in learning ESS learning was great, figure, animation, diagram/graph displayed were clear and easy to understand so it helps us to understand the concept easier and comprehensively." The student's testimonial in Figure 8 (b) gives evidence that "The aids of media visuals is help the student to learn and understand the concept and to display the abstract concept so that it as if it is real"

The result of a study by Bezen, Aykutlu, and Bayrak (2016) indicates that animation should be used to support the learning process effectively. The compilation of animation and visualization from GrADS were able to explain the concept and bring out the real condition of

the incoming solar radiation on Indonesian atmosphere. The visualization from GrADS that was presented in the learning activity also helped the student to have the ability to interpret the result of the analysis of the authentic data such as in applied science research. Figure 9 below can support Figure 6 to help the students construct the concept of the earth's revolution, incoming solar radiation, and annual solar movement.

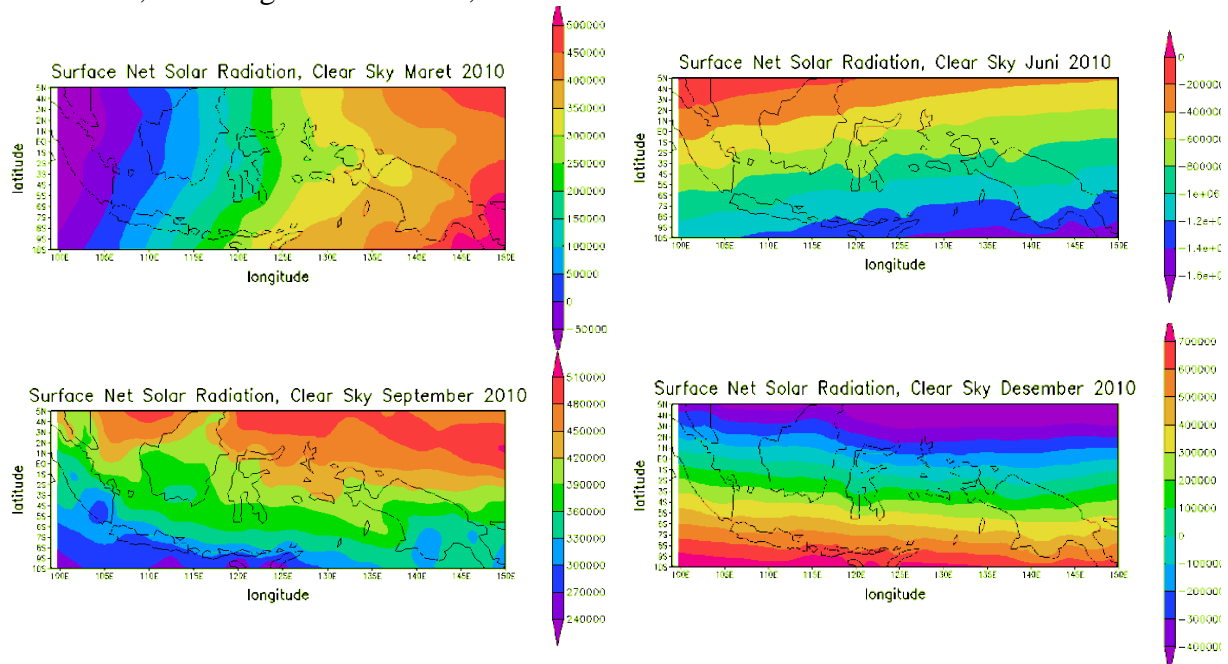


Figure 9. Incoming solar radiation in Indonesia's atmosphere in March, June, September, and December

This result was supported by the students' responses. They testified that animation helped them to understand concept. Animations helped them to visualize unobservable natural phenomena related to earth science. There was evidence that the students have obtained considerable benefits from the visualization used in the learning activities. The students' responses showed that all the students testify that the learning activities using visualizations were more interesting, made the understanding of the concept easier, especially the use of animations, and enabled them to explore their high order thinking. Based on the phenomena encountered by observation, we argue that the applied results of the analysis of authentic data using the GrADS in the learning activities gave them different experience learning about the real condition of solar radiation in the Indonesian atmosphere and helped the students to understand the concept clearly. Johan, Suhandi, Samsudin, and Wulan (2017b) revealed that analysis authentic data using GrADS also facilitated the student's reasoning skills. Similar with Ellwein (2014), it revealed that authentic scientific data can provide an engaging learning experience. Based on the student's responses, they recognized that visualization included animation, figure, graph, and display from GrADS facilitated their high order thinking. The animation that was used had the potential to explore logical thinking in the learning activities because it gave the dynamic situation of an object especially an unobservable object (Lowe, 2004). Kali (2003) stated that virtual visualization as a game in learning activity improved the students' enthusiasm or interest in learning. Kastens (2010) stated that the geoscience learning activity using visualization can give motivation and encourage students to enjoy the learning process. Motivation was an important factor for the learning activity (McConnell, 2011). The finding in this study was supported also by the qualitative analysis of open ended questions. Based on the responses to the open ended questions, the students provide evidence also that: visualization helped them to think about

the cause, effect, and relationships between concepts; the animation is very clear, helps to simplify concepts; the complicated concept becomes easier because of its visualization; animation makes learning activity more enjoyable, brings out curiosity, and is interactive.

Spiritual aspect

One of the aims of this study was to answer the spiritual attitude requirement of the INQF (KKNI). Spiritual attitude was based on the religious attitude competency in general description of the INQF (KKNI). This religious attitude competency was divided into spiritual attitude related to concepts of earth science and any phenomena in nature. Spiritual attitude in this study was related to awareness and belief in the divinity of God. The divinity of God in this study included awareness and belief in Godhead. Nature's divinity was that God is the infinite creator, infinite gracious, infinite assign, almighty, infinite nurture, and infinite wills. Basically, students had had a good spiritual attitude related to awareness and belief in the divinity of God before the intervention learning model. It was seen from the spiritual attitude before the learning process. Before the implementation of the learning program, their awareness and belief to divinity of God were at scale 8 to 10 in scale 1 to 10 (from no awareness and belief to having awareness and belief in the divinity of God). After the implementation, their awareness and belief in the divinity of God was at scale 9 and 10. The shifting of the students' spiritual attitude as a learning effect was indicated by the differences in the data before the implementation and after the implementation. According to the questionnaire in Table 5 above, after the implementation 97.8 % of the students' responses were at scale 10. Before the implementation, only 87.5% of the students' responses were at scale 10. It indicates that the learning process gave effect to improve the students' spiritual attitude. Beside it, the nature of earth science contributed also to improving the students' spiritual attitude. Natural science could bring out a transformation in the material side of our life while religion brings out the transformation of the spiritual side. In this case, absolutely science could not replace the function of religion but science and religion could support concurrently the human's life to be better in both the material and the spiritual sides. The separation of science from the religious aspect made it lose value and control for the science axiology side. This shows how important its value is in science.

Based on the qualitative data from the open ended questions, the students also provided evidence that exploring the spiritual value in earth science concepts successfully affected their belief in almighty God. Chain till unanswered questions in this study brings out the phenomena of tides as the effect of integration gravity from the earth and the moon. Students were guided by questions and feedback. Begin with Questions that can be answered by scientific reasoning:

"How can tides happen?"

"Why does the moon's gravity make tides?"

And then questions already cannot be answered by scientific reasoning:

"Why the moon and the earth have a mass the size and distance precision so that the tide may occur?"

After that student were given questions to embed the spiritual aspect related divinity:

"What happens if the size of the earth and the moon is greater so that force of gravity acting bigger than now?"

"What happens if the distance between the earth and the moon is made much closer, what happen to the tides?"

"What happens if the universe was created not in a very perfect precision?"

"Why is everything in the universe was created with great precision?"

"how and what is the aim of perfect precision of universe?"

These questions were aimed to guide the student to find the divinity in the universe with its perfect harmony. The students were engaged to discuss the questions above to embed the spiritual aspect. This is supported by the qualitative data from the students' responses to the open ended questions. A sample of student responses is available in Figure 10 (a) and (b).

Ibu Henny Johan menanamkan sikap spiritual kepada kami melalui pertanyaan "yang di luar nalar / yang tidak bisa di jawab dengan teori kepada kami. Disinilah kami lebih menyadari keberadaan Allah swt yang maha pencipta. Sikap spiritual ini perlu ditanamkan kepada Mahasiswa agar disamping memiliki ilmu duniya juga memiliki bekal akhirat.

(a)

a) Dalam menanamkan sifat spiritual baik dan materi, mahasiswa saat penjelasan bagaimana terjadinya hujan? Hujan adalah rahmat dari Tuhan, karena jika tidak terjadi hujan air tidak akan bersiklus dan hujan atau air bersih akan habis. Nilai spiritual dan mengajarkan konsep?

(b)

Figure 10 (a) and (b). Sample of student' evidence related to the embedding spiritual value

Student's response in Figure 10 (a) gives confirmation that "The lecturer embedded the spiritual value through unanswered questions in chain questions to lead us to be aware of God divinity and guided the student to the awareness of human finitude." Student testimonial in Figure 10 (b) gives confirmation that "the concept of rain embedded spiritual value related to God finite gracious. Rain is a part of the hydrological cycle."

Embedding a spiritual attitude also was got by presenting spiritual value in each concept. A sample of exploring concepts to embed spiritual attitude can be seen in Figure 11.

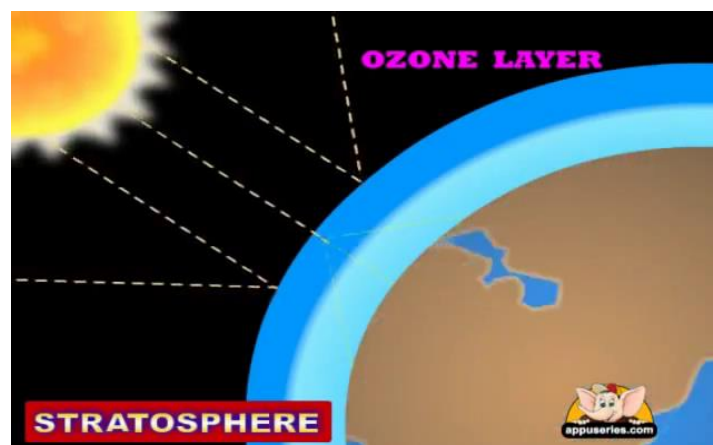


Figure 11. Ozone layer prevents UV from coming into the earth (Source: appuseries.com).

Embedding spiritual attitude was done by explaining the negative effect if the UV came into our earth. The existence of the ozone layer is aimed to protect humans from the negative effect of the UV from solar radiation. This perfect design of the atmosphere shows how God nurtures humans and everything on earth. The spiritual values related to how the nature of the Godhead needs to be explored in the earth's atmosphere phenomena. Johan, Suhandi, Wulan, and Samsudin (2017c) reported that the student got spiritual value of God's infinite nurture when the student learned the geomagnetism concept in ESS lesson. It strengthens the fact that ESS has a high potential to embed spiritual value. Exploring the spiritual aspect in learning

could be an alternative way of teaching science especially earth science. Similarly to Karwardi (2008), he revealed that integrated science and spiritual aspect in learning activity allowing the occurrence of complementation, comparison, inductive, and verification. The science concept was break-down to bring the concept of Godhead. In addition the results of the analysis indicated that the interactive activities in class by giving chain questions positively affected on the spiritual aspects. Charles Townes (2003) stated:

"I see religion as an attempt to understand the purpose of our universe and science as an attempt to understand its nature and characteristics"

Based on the study literature, similar research about embedding spiritual aspect in learning natural science especially ESS has not been reported widely.

CONCLUSION

Based on the results and discussions above, it can be concluded that the learning model IC-CUQ has the potential to improve the student's concept mastery and embedded spiritual attitudes related to belief in the Godhead. The student's concept mastery improve from no mastery to mastery level with the average N-gain being 0.8 (category high) with the help of visualization and compilation of authentic data analysis using GrADS. The display of authentic scientific data from GrADS helps students to understand the concept and gives them experience about the real condition in Indonesian's atmosphere. Visualization used in this study makes learning more interesting and explores their thinking skills. Multi modus visualizations visualized the details of the concept (phenomenon) clearly. Applying science research in the learning process gave some benefits, including: helping students to reason and to understand concepts, giving them different experience learning about real condition of nature, showing correlation among concepts, and providing enjoyable learning process. Embedding spiritual attitude in the learning activity was done through exploring the values of divinity in various phenomena and presented chain till unanswered questions at the end of learning process. It improved successfully students' spirituality.

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Scientific Inquiry Perception and Ability of Pre-service Teachers

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ABSTRACT

The research purpose was to assess the inquiry perception and ability of biology pre-service teachers. This research used mixed methods, with embedded design drawing on instruments adapted from the Principle of Scientific Inquiry – Teacher (PSI-T), inquiry ability test, and open questions list. Data analysis used descriptive statistics technique and independent sample t-test. The results showed high scientific inquiry perception and ability of pre-service teachers who used structure inquiry learning strategy in the classroom. There are no significant differences among scientific inquiry perception and the ability of pre-service teachers with respect to gender, but there are differences according to university. Pre-service teachers need to improve inquiry strategies in the classroom to the next levels, i.e., guided inquiry and open inquiry, which provides positive implications for students to be more independent and creative.

Keywords: Inquiry perception, Inquiry ability, Pre-service teachers.

INTRODUCTION

The acquisition of scientific inquiry has been one of the main goals of science education since 1960 (NRC, 2001). NSES (National Science Education Standard) since 2002 has drawn up standards at every level of inquiry, from the level of basic education to higher education. The inquiry is considered a very important strategy to encourage the learning of science (AAS, 1993; Çimer, 2007) and has become a major part of a teaching science reformation (Balim, 2009; Bulunuz, 2011). The practice of inquiry helps students develop knowledge concepts and understand scientific processes more clearly and deeply (NRC, 2000; Sahin, 2007). Some studies of the practice of inquiry have investigated the components of this, including hypothesis, theory, and interpretation of a phenomenon, which is critical to developing an understanding of science concepts (Muukkonen, Lakkala Hakkarainen, 2005; Llewellyn, 2002).

Inquiry-based teaching encourages students to exercise the thinking processes and creative activities conducted by scientists (Rutherford, 1960; Aktamış, Hiğde, Özden, 2016; Rees, Pardo & Parker, 2013). Inquiry provides an opportunity for students to conduct investigations and develop scientific concepts and ideas from their own experience (Parmin,



Sajidan, Ashadi, Sutikno, & Mareta, 2016). It also encourages students to observe scientific empiricism (Edward & Mercer, 1987, in Chen & She, 2015). For scientists, some of these components become important, especially in formulating research questions, designing and conducting informative investigations, and formulating persuasive opinions.

Scientific inquiry was a keyword in Indonesia's 2013 National Curriculum, referring to the scientific inquiry-based learning processes as the core of commonly known inquiry. The stages of inquiry include the ability to formulate problems, design experiments, collect data, and draw conclusions. Inquiry activities engage students in meaningful, creative, critical, and problem-solving-based learning. The 2013 National Curriculum necessitated the implementation of the scientific inquiry approach or scientific attitude in the learning process in the classroom (Kemdikbud, Indonesia Ministry of National Education, 2013). This learning process focuses not only on developing students' knowledge (cognition) and skills (psychomotor), but also their spiritual and social attitudes, and metacognition.

There have been a number studies looking at how to develop competence in teaching inquiry learning and pre-service teachers' perceptions of inquiry learning (Varma, 2007; Reaume, 2011). Varma (2007) studied teaching science using multi-methods inquiry-based learning integrated with teaching practice (field experience). She found that, through lectures, she was able to develop an inquiry understanding of pre-service teachers as well as its implications, and develop appreciation and confidence to create an inquiry environment in teaching. Related research by Reaume (2011) used an alternative instrument, open-ended semi-structured interviews, to investigate the development of perception inquiry of pre-service teachers. She reported a positive increase in perception in accordance with the increase of the teacher's education level and revealed time and classroom management to affect the success of inquiry learning.

In the Indonesian context, research over a teacher's efforts to develop inquiry ability was conducted by Anggraini (2005). She used a research and development method to find a form of lecture for General Biology of Inquiry Based Learning (BUBI) which effectively provides pre-service teachers the ability to inquire and master the concepts of the subject. Similarly, Amprasto (2016) developed an inquiry-based field trip program to improve the scientific ability and problem-solving skills of biology pre-service teachers. Nevertheless, both these studies have not clearly described how pre-service teachers can apply inquiry ability in the class, unlike other studies, which have provided pertinent information about the application of inquiry learning in the school context as well as at the level of inquiry being carried out.

One of the variables related to the application of the inquiry method is teacher perception of inquiry. This is because their level of inquiry perception will determine how effectively they can apply a method in the classroom. Campbell, Abd Hamid, & Chapman (2010) have developed an instrument of teacher's inquiry perception PSI-T in order to assess teacher competence in implementing inquiry learning in the classroom. Another research finding, MCLIC (McGill Classroom Level of Inquiry Checklist), offers quick reference criteria for the procedures to assess the level of inquiry in the classroom. This research recorded the application of inquiry learning directly in the classroom (Nuako, Shore, Saunders-Stewart, Gyles, 2015).

Both instruments above are able to measure perception inquiry, but are not equipped to measure the inquiry ability of pre-service teachers. Scientific inquiry capability is interpreted holistically not only as a positive perception in order to ensure the implementation of inquiry learning and comprehensive information. The implementation of scientific inquiry learning process, both in terms of quality and quantity in the classroom, can be shown through the acquisition of teachers' perceptions of inquiry. With respect to quality, we can measure the level of inquiry profiles that teachers enact in the classroom. With respect to quantity, the

levels of inquiry enacted by teachers in the classroom can be classified using a numerical score (see Table 2). So far, there is no empirical data describing the perception of scientific inquiry and inquiry ability that is actually held by a biology pre-service teacher.

Purpose

This paper goes beyond Campbell et al. (2001) by providing an opportunity to interpret and elaborate on the level of inquiry demonstrated by teachers. We do this by aligning perception scores with NSES inquiry levels, such as structured/discovery inquiry, guided inquiry, and free inquiry. Furthermore, it provides preliminary data on pre-service teachers' perceptions and inquiry ability, which is very important to teacher education curriculum reform.

The research questions addressed are: 1. What are the scientific inquiry perception and inquiry ability of pre-service teachers? 2. Do scientific inquiry perception and inquiry ability of pre-service teachers show a meaningful difference depending on gender and university? 3. Do scientific inquiry perception and ability of a pre-service teacher of a particular gender show meaningful difference depending on different university? All the information was required synergistically as initial data for developing the biology teacher education courses that integrate the ability of inquiry. The data simultaneously describes the capacity of biology pre-service teachers undertaking the teacher education program to implement the 2013 Indonesian National Curriculum, in particular, the inquiry learning process.

METHODS

a) Methodology of Research

This research used mixed methods with embedded data. The researcher has been embedding secondary data (qualitative) into the primary data (quantitative) in one study, the secondary database supporting role in this research (Creswell & Plano Clark, 2011). A quantitative study was conducted by disseminating the PSI-T instrument and the inquiry ability test, then a qualitative study was conducted purposively for a number of students to be interviewed.

b) Sample of Research

The research subject was 90 biology pre-service teachers from the Biology Education Department of two state universities in Jakarta, namely University A (49) and University B (41). They are in the 8th semester, and had completed all courses and followed the Teaching Practice (PPL). Both programs require students to do a teaching internship in school for about 4 months under the guidance of the teacher tutors and lecturers. The teaching internship included some apprenticeship stages, such as classroom observation, consultation, real teaching, and feedback provision by the teacher tutors and lecturers. Pre-service biology teachers who wish to do this internship should have already taken prerequisite courses related to the content and pedagogy.

c) Data Collection Tool

The research instrument was distributed to all students at each university in the classroom setting simultaneously for each instrument. Questionnaire PSI-T and inquiry ability test were distributed to pre-service teachers. The time allocated for the questionnaire would be 30 minutes and the inquiry ability test for 60 minutes.

Furthermore, in-depth interviews were conducted with 12 pre-service teachers from both universities (Table 1) to identify and confirm the answers they provide when filling out the questionnaires and tests. Determination of students' acquisition based on inquiry ability

with three levels is categorized as high, medium, and low level. The interview was audio taped for about 100 minutes for all student in each university.

Table 1. The distribution of biology pre-service teachers according to gender and inquiry ability score from two universities (University A & University B)

University A	Gender	University B	Gender	Inquiry ability score
X1	Woman	Y1	Woman	High Category
X2	Woman	Y2	Woman	High Category
X3	Woman	Y3	Woman	Middle Category
X4	Woman	Y4	Woman	Middle Category
X5	Woman	Y5	Woman	Low Category
X6	Man	Y6	Woman	Low Category

Question on Interviews

Three questions were asked at the interview, i.e:

Question 1: Explain the meaning of Inquiry Learning Model.

Question 2: Which parts of inquiry ability item are considered difficult?

Question 3: Give your opinion: is your practical experience with themes on the item required when you graduated and taught at school?

Instrument

Principle of Scientific Inquiry Teacher (Psi-T) Instruments

PSI-T instruments developed by Campbell et al. (2001) consist of 20 statements that include five principles of inquiry: (A) framing research questions, (B) designing investigations, (C) conducting investigation, (D) collecting data, and (E) drawing conclusions. The PSI-T has been adapted and validated both linguistically by language experts and science education experts. The pilot study of 30 biology teachers obtained 20 valid statement which were tested with Cronbach alpha test values ($r = 0.83$). PSI-T has used a Likert scale with a description: 1 = almost never, 2 = seldom, 3 = sometimes, 4 = often, 5 = almost always. The adjustment scale discussed has been validated by a science education expert to describe the information as meaningful. The maximum score for PSI-T was 100.

Inquiry Ability (Ia) Test Instruments

Inquiry ability instruments in the form of 10 items described the biology concept integrated with IA. The IA in this study was limited to (1) define a problem, (2) identify the variables, (3) develop a hypothesis, (4) plan trial (drafting tool materials, making research procedures and predicting data obtained). Instruments were validated by the science education experts. The maximum score for IA was 100.

d) Data Analyzed

Questionnaire data were analyzed descriptively to gage inquiry perception and IA of pre-service teachers. All data of inquiry perception and IA calculated the mean score and SD and specified categories of scores to Campbell et al. (2010) (Table 2). Finally, to examine the question “Do scientific inquiry perception and IA of pre-service teacher have meaningful difference according to gender and university?,” independent t- test with statistical analysis package SPSS 22 (Statistical Package for Social Sciences Program, Version 22) was used.

Table 2. Score category for inquiry ability and PSI-T

Score	Category
1–33	Low
34–65	Middle
66–100	High

FINDINGS AND DISCUSSION

Quantitative Data

1. Category of Scientific Inquiry Perception (SIP) and Ability of Pre-service Teacher

The three research questions will be discussed in this article are: What are the category of SIP and IA of pre-service teachers? Three categories have been determined, i.e., high, middle, and low for both inquiry perception and ability.

Table 3. Percentage of scientific inquiry perception of pre-service teachers from two universities

Participants	Low		Middle		High	
	N	%	N	%	N	%
University A	1	2	24	49	24	49
University B	0	0	10	24	31	76
Total	1	1	34	38	55	61

Table 3 shows the percentage and category of SIP of pre-service teachers. The findings show that the SIP of pre-service teacher dominated in the high category (61%), medium category (38%), and only 1% in the low category. University A has the same SIP score with medium and high categories (49%) and 2% of a low category. University B has 76% in the high category, 24% in medium category, and 1 % in the low category.

Table 4. Percentage response of scientific inquiry perception

PSI-T	Scale									
	almost never		seldom		sometimes		often		almost always	
	N	%	N	%	N	%	N	%	N	%
Asking questions (A)	4	4,44	15	16,67	37	41,67	30	33,33	4	4,44
Designing investigations (B)	4	5,00	17	18,33	30	33,61	30	33,06	9	10,00
Conducting investigation (C)	5	5,28	9	10,00	22	24,44	39	43,06	15	17,22
Collecting data (D)	3	3,61	9	10,28	32	36,11	36	39,44	10	10,56
Drawing conclusions (E)	2	2,50	8	9,17	31	34,44	37	41,11	12	12,78

Based on Table 4, there was gradation response in the SIP of pre-service teachers. From Table 4, it can be seen the positive response from SIP of pre-service teachers in each component of principle inquiry (scale often and almost always) is greater than the negative response (scale almost never and seldom). This shows that the prevalence of inquiry learning has been implemented of a pre-service teacher in the classroom.

Table 5. Percentage negative response of scientific inquiry perception

Sub of PSI-T	Scale									
	almost never		seldom		sometimes		often		almost always	
	N	%	N	%	N	%	N	%	N	%
B2*	5	5,56	22	24,44	42	46,67	17	18,89	4	4,44
B4*	9	10,00	27	30,00	41	45,56	13	14,44	0	0
C1*	15	16,67	26	28,89	33	36,67	13	14,44	3	3,33

*negative response

However, as shown in Table 5, there are negative responses from sub-principle scientific inquiry, i.e., B2, B4, and C1. The following description indicates the perceived negative response:

- (1) B2. Students design their own procedures for investigations;
- (2) B4. Students justify the appropriateness of the procedures that are employed when they conduct investigations;
- (3) C1. Students conduct their own procedures of investigations.

Table 6. Percentage of inquiry ability of pre-service teachers from two universities

Participants	Low		Middle		High	
	N	%	N	%	N	%
University A	4	8	7	14	38	78
University B	8	20	11	27	22	54
Total	12	13	18	20	60	67

Table 6 shows the percentage of IA of pre-service teacher from two universities. The findings show that the IA of pre-service teachers dominated in the high category (61%), medium category (20%), and 13 % in the low category. University A has 78% of the high category, 14 % in the middle, and 8% in a low category. University B has 54% of the high category, 27% of the medium category, and 8% in a low category. A profile of IA can be seen in Table 7, which can help understand the IA of pre-service teachers better in formulating problems and developing hypotheses.

Table 7. Inquiry ability of pre-service teachers

Inquiry Ability	Mean	SD
A. Formulating Problems		
Identifying variables	55,90	21,54
Formulating problem	85,11	29,19
Developing hypotheses	83,88	28,86
B. Planning Experiment		
Drafting tool materials	54,75	20,26
Developing research procedures	58,10	27,83
Predicting data to be acquired	21,26	23,51

2. Scientific Inquiry Perception and Inquiry Ability of Pre-service Teacher with Gender

The second problem of the study has been determined as “Do SIP and IA of a pre-service teacher show meaningful difference depending on the gender?” There is 11% males compared with 89% female pre-service teacher.

Table 8. Result of t-test score of scientific inquiry perception of pre-service teachers according to gender

Gender	N	X	SD	Levene`s Test F	Sig	t (df)	Signf
Male	10	73	8.11	0.426	0.516	1.697 (88)	0.093
Female	80	67	10.85				

***Significance ($p < 0.05$)**

As is seen from Table 8, it was found that there was not a significant difference among the SIP of male and female pre-service teachers ($t(88) = 1.697$; $p > 0.05$). It can be reported that the mean scores SIP of a male was 73 and female 67.

Table 9. Result of t-test inquiry ability of pre-service teachers according to gender

Gender	N	X	SD	Levene`s Test F	Sig	t (df)	Signf
Male	10	56	18,27	0.033	0.857	-1.296 (88)	0.198
Female	80	65	20.93				

***Significance ($p < 0.05$)**

As is seen from Table 9, it was found that there was not a significant difference among the score IA of male and female pre-service teachers ($t(88) = -1.296$; $p > 0.05$). It can be reported that the mean scores IA of male was 56 and female 65.

3. Scientific Inquiry Perception and Inquiry Ability Pre-service Teacher with university

The third problem of the study has been determined as “Do SIP and IA of a pre-service teacher of a particular gender show meaningful difference depending on different university?”

Table 10. Scientific inquiry perception of pre-service teachers with university

University	N	X	SD	Levene`s Test F	Sig	t (df)	Sign
A	49	65	10.64	0.80	0.779	-3,058 (88)	0.003*
B	41	71	9.75				

***Significance ($p < 0.05$)**

Table 10 shows that there was a meaningful difference in SIP depending on different universities. The t-test results of the difference university with ($t(88) = -3,058$; $p < 0.05$).

Table 11. Independent t-test SIP for gender

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2- tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Asking questions	,781	,379	2,234	88	,028*	1,863	,834	,206	3,519
Designing investigations	,009	,927	,877	88	,383	,725	,827	-,919	2,369
Conducting investigation	,001	,971	1,636	88	,105	1,413	,863	-,303	3,128
Collecting data	,576	,450	1,398	88	,166	1,325	,948	-,558	3,208
Drawing conclusions	1,375	,244	,711	88	,479	,713	1,002	-1,278	2,703

*Significance ($p < 0.05$)

In order to see if pre-service teachers differ in their SIP according to gender, a t-test for independent samples have been used and the results indicated that they differ only in asking questions ($p < 0.05$; Table 11).

Table 12. Inquiry ability of pre-service teacher with university

University	N	X	SD	Levene's Test		t (df)	Sign
				F	Sig		
A	49	69	17.29	0.80	0.016	-3,058 (88)	0.009*
B	41	58	23.04				

*Significance ($p < 0.05$)

Table 12 shows that there was a meaningful difference of IA of pre-service teacher depending on the different universities. The t-test results of the difference according to university was found to be ($t(88) = -3,058$; $p < 0.05$).

Table 13. Independent t- test inquiry ability according to gender

IA	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2- tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Identifying variables	,700	,405	-,902	88	,369	-6,52500	7,23271	-20,89849	7,84849
Formulating problem	,043	,836	-,815	88	,417	-8,00000	9,81013	-27,49557	11,49557
Developing hypotheses	,034	,854	-,799	88	,426	-7,75000	9,70038	-27,02746	11,52746
Drafting tool materials	2,446	,121	-1,053	88	,295	-7,15000	6,79306	-20,64979	6,34979
Developing research procedures	,000	,997	-1,418	88	,160	-13,16250	9,28471	-31,61391	5,28891
Predicting data to be acquired	,516	,474	-1,636	88	,105	-12,78750	7,81471	-28,31760	2,74260

*Significance ($p < 0.05$)

In order to see if pre-service teachers differ in their IA according to gender, t-test for independent samples was used and the results indicated that there is no meaningful difference ($p < 0.05$), as seen in Table 13.

DISCUSSION

The results showed that most of the perception of scientific inquiry and IA among pre-service teachers has a high category (61% vs 67%) and there are no significant differences with gender. Instruments of teacher perception provide prevalence information about the teachers' implementation of the inquiry strategy in the classroom. Instrument PSI-T is in line with the instrument RTOP that describes teachers' realization of inquiry strategy in the classroom (Campbell et al., 2010).

Another research finding was that the perception of scientific inquiry and IA among pre-service teachers has significant difference according to university. The results above are consistent with the results of interviews with pre-service teachers focusing on inquiry-based learning in lectures. Pre-service teachers of all categories in two universities have understood the meaning of inquiry as a process of discovery, but the students' IA of high and medium category was better in defining the appropriate inquiry learning understanding as its essence, that one of the keywords of inquiry is evidenced through scientific methods (Bianchini & Solomon, 2002; Ramey-Gassert, Shroyer, & Staver, 1996).

The research result is in line with Alhendal & Dalal (2015), who reported that 496 public elementary school teachers in Kuwait used inquiry significantly in their capacity to inquire in the classroom. Although science teachers in Kuwait showed positive attitudes associated with the implementation of inquiry teaching, there are factors that limit the use of in the classroom.

Judging from the complexity of inquiry learning, there are three levels: structured inquiry, guided inquiry, and free inquiry (NSTA, 2002). In structured/discovery inquiry, students are invited to make discoveries through scientific activities involving the basic ability of scientific work, such as asking, formulating a problem, interpreting, proving evidence, and concluding. While the setting of guided inquiry problem submission is determined by the teacher and the open inquiry is based on the direction of the teacher, students are challenged to formulate their own problems, which can bring up questions on an activity in further learning. This process of inquiry provides students with the opportunity to develop self-reliance, creativity, and innovation.

Interviews showed that all pre-service teachers implement the inquiry learning strategy in biology class by setting discovery/structured inquiry. These results are consistent with the score of inquiry perception that shows the pattern of inquiry levels to be the most dominant in structured/discovery inquiry. This is shown in the data patterns of negative response perceived by pre-service teachers at both universities (as seen in Table 5). There are three negative responses from statements of Principal Scientific Inquiry, such as:

“B2. Students design their own procedures for investigations; B4. Students justify the appropriateness of the procedures that are employed when they conduct investigations; C1. Students conduct their own procedures of investigations”

Campbell et al. (2010) state that category (*formulating problem, designing experiments, and conducting investigations*) as the main guarantor of inquiry experience has been used in the classroom. It gives a real impact if teachers change from traditional teaching patterns into inquiry strategies that allow students to engage actively in investigating and drawing conclusions (*collect data and conclude*). Based on the result of perception on scientific inquiry, it can be noted that pre-service teachers have made some progress in implementing the inquiry strategy in their class.

It provides information that pre-service teachers are able to develop *a scientific research planning*. However, it is important to get attention primarily on the ability to identify the variables. Pre-service teachers are able to identify independent and dependent variables as supported by the good scores in developing hypothesis ability and formulating the problem. However, the inability of pre-service teachers to determine control variables is still found, and

gives them low score in identifying variables. The same pattern was reported by Hofstein, Navon, Kipnis & Mamlok-Naaman (1987), who applied the inquiry approach that helps students ask questions better than traditional approaches. Students have a substantial issue in the inquiry process, such as the difficulties in expressing tested hypotheses and selecting the right variables (Madden, Baxter, Beauchamp, Bouchard, Huff, Ladd, Pearson, & Plague, 2013; Soprano & Yang, 2013).

Table 14. Quantitative and qualitative findings

Quantitative Findings	Qualitative Findings
Inquiry perception and inquiry ability of both universities most have the high category with tendencies of structure inquiry learning strategy patterns.	<p>It was found from the interviews that pre-service teachers at both universities found that it is difficult to <i>design experiments</i>, specifically because of the following:</p> <ol style="list-style-type: none"> (1) Confusion about what kind of data that can be obtained because it is possible to identify several of the variables [it shows that pre-service teachers already have predictive ability, but not sure how to answer]; (2) They do not understand the concept [lack preliminary knowledge]; (3) They are lack of reading references [low literacy]; (4) Has never been experienced laboratory theme in case of Biotechnology [need models/examples of relevant learning experiences]. <p>The pre-service teacher has taught structure inquiry learning strategy.</p>

The quantitative and qualitative findings are shown in Table 14. The interviews show the difficulties of pre-service teachers at both universities related to *designing an experiment*. The three components of that inquiry are part of *designing an experiment*. These preliminary results are in line with Anggraini (2006), who stated before intervention with inquiry-based Biology Course Program (BUBI) that biology pre-service teachers have a low ability to *design experiments*. Implementation of the BUBI course has proven its effectiveness to equip IA for pre-service biology teachers. The inquiry abilities (formulating hypotheses, planning experiments, observing, analyzing data) showed highly significant differences compared to the control class. Through inquiry-based course debriefing from the beginning, the students become experienced to inquire and have an idea of how inquiry-based learning is carried out. It builds their confidence and motivation to apply inquiry-based learning later in their career.

IA or scientific work ability is the integration of knowledge and skills that demonstrate learning outcomes in the long term (Haladyna, 1997). This IA performance is in line with the research results of Zulfiani (2006), who stated that inquiry development program on biotechnology can improve the IA performance of pre-service teachers, despite the lower performance in planning the experiment's ability (structured inquiry and free inquiry).

The results of the study suggest that the integration is considered important to Teacher Education Program, as institutions which produce teachers are increasingly being challenged by the rapid development of science and technology. It is expected that the IA given will become a "tool" for students/ pre-service teachers to maintain the existence of "life and

living.” The IA is supposed to be “familiar with” the students/pre-service teachers because it indirectly gives concrete examples of instilling an inquiry learning culture (*knowing the investigation process*). The sustainability of this implementation is that the lecturer can develop a learning program that integrates the IA in the course (Bryce, Wilmes & Bellino, 2016), developing knowledge and skill on inquiry learning as meaningful learning (Ohn, 2013). Integration was developed at the level of the study program curriculum, syllabus, and lecture plan that integrates IA into biological knowledge. A lecturer in the field of study should be able to provide experience to students that science is not merely a *product*, but as the *process and attitude* (Biggers & Forbes, 2012). To achieve this, the lecturer should provide guidance and examples to students so that the character of inquiry is strongly embedded.

Çalik, Ebenezer, Özsevgeç, Küçük, & Artun (2015) reported that a Model Technology Embedded Scientific Inquiry (TESI) is a form of integration of technology and IA which have an important role in shaping and strengthening the Professional Teachers Program, which can improve technology fluency and eliminate the barrier between teachers and pre-service teachers and technology literacy. This model is recommended in Teacher Education Programs as a catalysis in the reform of teacher education to connect disciplines and constraints in the classroom. If pre-service teachers integrate technology into teaching, it will be useful to professionalism in the future.

The IA on NSES is gradual and continuous, and this ability is integrated into every subject, from primary education to higher education (Zion, Cohen & Amir, 2007; Tseng, Tuan & Chin, 2013). The IA requires each student to support their life (Plevyak, 2007). Pre-service teachers in teacher education have the mission of implementing IA in school. Pre-service teachers, without exception, have the duty to internalize IA from the beginning of their teacher education program, because, as Anggraini (2006) asserts, the earlier the ability is introduced to student teacher, the easier it will be to understand the urgency of their IA. This is consistent with Barrow (2006) in (Varma & Hanuscin, 2009), who stressed the need for standards of inquiry in the higher level that can guide students to achieve their IA.

Furthermore, Amprasto (2016) asserts that pre-service teachers need concrete examples like field trip design experience that can be implemented in their future teaching at a school. Inquiry-based field trip design program has proven to improve scientific work and problem-solving. The integration of IA in the course is the main thing to be urgently addressed (Varelas, Pappas, Kane & Arsenault, 2008; Minner, Levy & Century, 2010). Particularly, the courses in the teacher education program involve more than just transferring knowledge to students (Nowicki, Sullivan-watts, Shim, Young & Pockalny, 2013).

CONCLUSION

Perception of scientific inquiry and IA among pre-service teachers have mostly a high category and used to structure inquiry learning strategy in the classroom. Pre-service teachers need to improve the inquiry strategy quality in the classroom to the next levels, i.e., guided inquiry and open inquiry, which provide positive implications for students to be more independent and creative.

There is no significant difference between SIP and IA of pre-service teacher with gender, but have significant difference according to university. The low IA of pre-service teachers, such as identifying variables, drafting tool materials, developing research procedures, and predicting data to be acquired indicates that the integration of scientific inquiry skill with the course content is required. This is especially urgent when a learning institution aims to redesign its biology content for pre-service teachers.

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