

The Effectiveness of RMS Learning Model in Improving Metacognitive Skills on Science Basic Concepts

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ABSTRACT

This study aimed at: 1) Examining the effect of RMS learning model to metacognitive skills. 2) Examining the effect of different academic abilities against metacognitive skills. 3) Examining the effect of interaction between RMS learning model and different academic abilities against metacognitive skills. This study is quasi experiment which employed pretest and posttest non equivalent group design. The instrument of this study was essay test with high level of reliability 0.712. Descriptive analysis and ANACOVA statistical analysis were applied to analyze the obtained data. The results showed that RMS learning model effectively improved metacognitive skills and able to aligned students' metacognitive skills in different academic abilities. The highest indicator metacognitive skills are shown on the indicator planning with descriptions set goals with a value of 90%. The impact of RMS learning models was 51.5% higher than conventional models on metacognitive skills.

Keywords: Metacognitive Skills, RMS Learning Model, Science Basic Concepts.

INTRODUCTION

a) *the Importance of Metacognitive Skills and Problem in Students*

The improvements in education system keep continuing in order to achieve optimal educational goals. The improvements may include curriculum improvement, quality of teachers, and the quality of the learning process. Education is important in creating qualified and competitive human resources.

Quality of human resources is a challenge for 21st century and for the upcoming centuries. A challenge with there is no time and state of origin boundaries. The countries equipped with superior human resource will win the global competition. Higher-level of thinking is one of the skills needed in the 21st century. It includes metacognitive skills, problem solving, critical thinking, analytical thinking and evaluation (assessing possible alternatives, assessing arguments, weighting evidences, considering different opinions, finding cause/effect relationships, evaluating possibility), creative thinking and innovativion, and capable of producing new ideas from old ideas (Riechman & Simon, 2013).



Metacognitive skills is one of the high level of human thinking skills about their thinking process itself (Greenstein, 2012). Thinking awareness associated with one's awareness of what is known and what will be done (Syaiful, 2011). The metacognition occurs in the usage of prior knowledge to plan strategies to do chores, take the necessary steps to solve the problem, reflect and evaluate the outcome (Teal, 2010).

The components of metacognitive skills are metacognitive knowledge and metacognitive skills (Syaiful, 2011). The metacognitive knowledge is cognition knowledge. In general it is same with the awareness and someone's cognition knowledge. The metacognitive knowledge consists of three aspects, namely: strategic knowledge, cognitive tasks knowledge, including contextual and conditional knowledge, and self-knowledge (Krathwohl, 2002). The metacognitive skills are related in planning skills, prediction skills, monitoring skills, and evaluation skill (Sarac et al., 2014).

The metacognitive skills associated with general intelligence of human that can be used as reference or indicator of successful learning which is being able to explain the academic achievement coverings the intelligence and performance in learning (Gomes et al., 2014; Sarac et al., 2014). The metacognitive skills can be taught and developed through basic concepts in science subject. As the matter of facts, students' metacognitive skills related to basic concepts in science subject at PGRI Semarang University is less optimal as shown by the low criteria of overall metacognitive skills value (49%) (Muhlisin, et al., 2016).

Empowerment of the metacognitive skills in learning context is performed to create independent learners (Corebima, 2009). It needs planning process, implementation, monitoring, and good evaluation (Haribhai, 2012). Having the metacognitive skills will ease someone to be able to regulate and control the learning process (Veenman et al., 2014), select the goals, select a strategy (Mir, 2015), understand how people learn, understand the capabilities and own learning modalities, and understand the best learning strategies for effective and efficient learning (Romli, 2012; Mursinah, 2013), so that success in learning will be used to solve daily life problems. In this reality, it is teacher's responsibility to be able to transfer any information and knowledge deals with common problems in daily life (Cepni et al., 2017).

The metacognitive skills empowerment in the learning process is affected by method or the learning model (Saglam&Sahin, 2017) and the variety of students' academic ability (Muhlisin et al., 2016). The methods or learning models used at the basic concepts in science subject are less empowers metacognitive skills. The learning process is less able to improve student thinking in planning, choosing a strategy, controlling, and evaluating. Castro & Morales (2017) mentioned that learning should be able to involve learners through keeping active and motivate in learning to spontaneously enable finding success and difficulty in learning.

The metacognitive skills is second-order cognition that has a mining of thinking about thinking, knowledge of knowledge, or a reflection about actions (Weinert&Kluewe, 1987). The metacognitive skill is a way for students to rearrange their way of thinking by reviewing the goals, how to achieve them, how to overcome obstacles, and evaluation. Learning suggesting the meaningfulness could foster high level thinking. The increase in the metacognitive skill in sciences learning, according to Iskandar (2014), could be developed in various ways such as by giving a space for learners to be able to plan an approach for the given assignments, monitoring the understanding, and evaluating the progress in the assignment completion. The metacognitive skills is an ability to think where the object of the thinking is the thinking process occurs in oneself.

Another study in developing college students' metacognitive skill is by giving them problems during the learning process since solving problems means that the students are able to learn and process information. Thus, select an appropriate strategy in accordance with the

problems faced and monitor the progress in learning as well as correct any mistakes occur during concept understanding and analyze the effectiveness of the selected strategy (Iskandar, 2014). A meaningful and real experience-related learning activity could improve the metacognitive skill of college students (Danial, 2010). "Group investigation strategy" is used to train in synthesis, analysis, and evaluation. Thus, it able to improve the metacognitive skill (Slavin, 2005).

The learning process is also putless attention to the variety of students' academic level. The division of the group based on the students' willingness in which resulting homogenous group. It means that only one group consists of high academic member and the others consist of low academic members. The process of preparing group paper is often dominated by the high academic ability of students (Muhlisin et al., 2016). The method or model of learning becomes important to be able to accommodate the gap between high and low academic ability students.

b) Purpose

This study aimed at: 1) Examining the effect of RMS learning model to metacognitive skills. 2) Examining the effect of different academic abilities against metacognitive skills. 3) Examining the effect of interaction between RMS learning model and different academic abilities against metacognitive skills.

A research on metacognitive skill is based on a research by Danial (2010) stated that learners tended to be passive at class in receiving lessons, they were more silent, and they were listening, writing, memorizing however, they could feel bored and in turn, they were not conscious during the learning process.

The current situation of college students is having low metacognitive skills, S not know their group members and their group presentation schedule, less independent in performing discussions without lecturer's supervision, and often late in delivering the assessment (Muhlisin, et al., 2016).

c) Metacognitive Skills

Metacognition is thinking about something with all details (Greenstein, 2012). Metacognitive awareness related to someone's thinking about the thinking process itself. Awareness of thinking associated with one's awareness of what is known and what is to be accomplished (Syaiful, 2011). The metacognition is an ability of a person to use previous knowledge in planning strategies do chores, take necessary steps to solve the problem, reflect on and evaluate the results (Teal, 2010).

Metacognitive skills classified among the higher cognitive abilities because it includes several elements such as analysis, synthesis, and evaluation. The metacognitive skills are very important for training learners to think critically and be able to plan, control, and reflect all the activity of thinking that has been performed (Iskandar, 2014). Anderson & Krathwohl (2001) defined three indicators of metacognitive skills as planning, evaluation, and monitoring. Indicators and description of metacognitive skills can be seen in Table 1.

Table 1. Indicators and Descriptions of Metacognitive Skills

No	Indicator	Description
1.	Plan	<ul style="list-style-type: none"> • Setting goals • Enabling relevant resources • Choosing the right strategy
2.	Evaluation	<ul style="list-style-type: none"> • Determine the level of understanding of a person • How to choose the right strategy
3.	Monitoring	<ul style="list-style-type: none"> • Checking one's progress • Choose the appropriate improvement strategies when the chosen strategy does not work.

Source: Anderson & Krathwohl (2001)

Efforts to improve learning outcomes can be made by improving metacognition of learners. Coutinho (2007) have uncovered a positive relationship between metacognitive skills and academic achievement. The learning achievement of someone who has a high metacognitive level would be better if compared to those with low metacognitive level.

Learners are routinely being asked to think about how to bring the knowledge and skills, writing about what they know and want to know, appreciate how they understand, and consider how they can monitor and manage their thoughts and actions (Greenstein, 2012: 86).

d) RMS (Reading Mind mapping, and Sharing) and Conventional Learning Model

RMS (*Reading Mind mapping, and Sharing*) learning model that includes learning phase, the activities of lecturers, and student activities can be seen in Table 2.

Table 2. Activities in Learning Model RMS

Instructional Design of RMS
Learning procedures
Phase One: Introduction
<ol style="list-style-type: none"> 1. Greet the students and ask them to pray before the learning begins. 2. Checking students' attendance. 3. Communicate/state the learning objectives, expected final abilities, and rules in learning. 4. Motivate and stimulate the students' curiosity about the related topics. 5. Distribute and explain the instructions in the students' worksheets 6. Assign the students to work as instructed in the students' worksheets
Phase Two: Main Activities
Reading
<ol style="list-style-type: none"> 1. Students read the related topics or particular material critically by analyzing the purpose and content of reading passages.
Mind mapping
<ol style="list-style-type: none"> 1. Students make a mind mapping related to the results of reading individually. 2. Students make mind mapping in a collaborative group.
Sharing
<ol style="list-style-type: none"> 1. Students present the results of the group mind mapping in front of the class. 2. Students give feedback/questions related to the work of the group who present their work results. 3. Lecturer confirms/strengthens related to the topics/material/concepts learned.
Phase Three: Closing
<ol style="list-style-type: none"> 1. Facilitate each group for reflection and evaluation of the learning instruction in order to be able to identify strengths, weaknesses, and choice in learning. 2. Ask the students to pray and partings.

In this research, conventional learning model was used as the learning model for the lecture on the basic concepts of science with or without adopting a particular instructional model. In each lectures, students in groups are required to prepare papers, presenting papers, and frequently asked questions according to process of conventional learning model

METHODS

This research is quasi experimental research which conducted on November 2014 to August 2015. It was conducted in basic concepts in science subject on PGRI Semarang University.

a) Research Design

The quasi-experimental research design was adopted with a 2x2 factorial nonequivalent group design version. Nonequivalent quasi-experimental pretest-posttest control group design procedure is further shown in Table 3.

Table 3. *The Procedure of Experimental Research Implementation*

<i>Pretest</i>	<i>Treatment</i>	<i>Posttest</i>
O1	A1B1	O2
O3	A1B2	O4
O5	A2B1	O6
O7	A2B2	O8

Notes: O1, O3, O5, O7: pretest scores

O2, O4, O6, O8: posttest scores

A1: lecturing by using RMS learning model

A2: lecturing by using conventional learning model

B1: a group of students with higher academic ability

B2: a group of students with lower academic ability

b) Sampling

The study groups were determined according to academic ability which was based on students' Grade Point of odd semester of academic year 2014/2015 that divided into three items, namely high ability (HA), moderate ability (MA), and low ability (LA). The students in high ability and low ability groups were examined in this research. The high ability student group was considered as 33.3% of the students on the top of the list based on the Grade Point (GP). The low ability student group was considered as 33.3% of the students on bottom of the list based on the Grade Point (GP).

The character of college students in the research before the implementation of RMS learning model was that they were unable to do planning in preparing themselves in the learning. The students were less able in monitoring on the assignments given and in evaluating themselves in their learning achievement. This can be seen from the readiness of students in learning who do not know what material to learn and often late in collecting assignments.

The college students were students of the first semester in the lectures structure in Indonesia. The average age of the students was 18 years old. At that age, students should have developed metacognitive skill needed for the success of study during their undergraduate degree program before they could go to the next level.

The participants of this study were students who receive the basic concepts of science subject. There were 418 students which divided into 9 classes. Cluster random sampling technique was applied and chosen two classes at random as participants:

1. 2A class (class control/conventional class) consisted of 45 students where 15 students were at high academic ability (HA) and 15 students were at low academic ability (LA), and
2. 2C class (experimental class/classroom learning using RMS model) consisted of 48 students where 16 students were at high academic ability (HA) and 16 students were at low academic ability (LA).

c) Instrumentation

The research instruments were observation sheet, student observation sheet, and metacognitive skills test. The observation sheet was used to measure if the learning process ran well or not. The student observation sheet was used to observe the students' activity. The metacognitive skills test consisted of 18 questions that integrated to metacognitive skills

indicators such as planning, monitoring, and evaluation (Krathwohl, 2002). The level of reliability of the test was 0.712. Metacognitive skills rubric consisted of seven scale (0-7) which includes: (1) the answer in his own words, (2) the order of a coherent answer, (3) the grammar or language, (4) the reason (analysis/evaluation, creation), and (5) answer (right/less/not really/blank) (Corebima, 2009).

d) Data Analysis

The data analysis techniques were descriptive statistics and inferential statistics techniques for parametric data distribution. The research data from the results of the metacognitive skills tests were then analyzed by the Anakova test which was preceded by the normality test and homogeneity test. The results of the normality test and homogeneity test are seen in Table 4.

Table 4. Normality Test and Homogeneity of the Value of Metacognitive Skills Test

<i>Test</i>	<i>df</i>	<i>P Value</i>	<i>Criteria</i>	<i>Conclusion</i>
<i>Test of Normality</i>	62	0,200	$\rho \geq 0,05$	Normal
<i>Test of Homogeneity of Variances</i>	60	0,751	$\rho \geq 0,05$	Homogen

Based on the calculation of Table 4 on the test of normality, the significance value is greater than 0.05, which is 0.200, which means that the data is normally distributed. In the test of homogeneity of variances, the significance value is greater than 0.05, which is 0.751, which means that the data is homogeneous. The descriptive analysis was used to describe the data of students' metacognitive skills. The parametric inferential statistics analysis technique was applied to examine the data of students' metacognitive skills using ANCOVA (covariance analysis) analysis with SPSS 20 for Windows.

FINDINGS

The students' metacognitive skills score was obtained from the pretest and posttest. Tests were essay that consisted of 18 questions for both control class (conventional learning models) and the experimental class (RMS learning model) as well as for high and low academic ability students. The recapitulation of the metacognitive skills score can be seen in Figure 1.

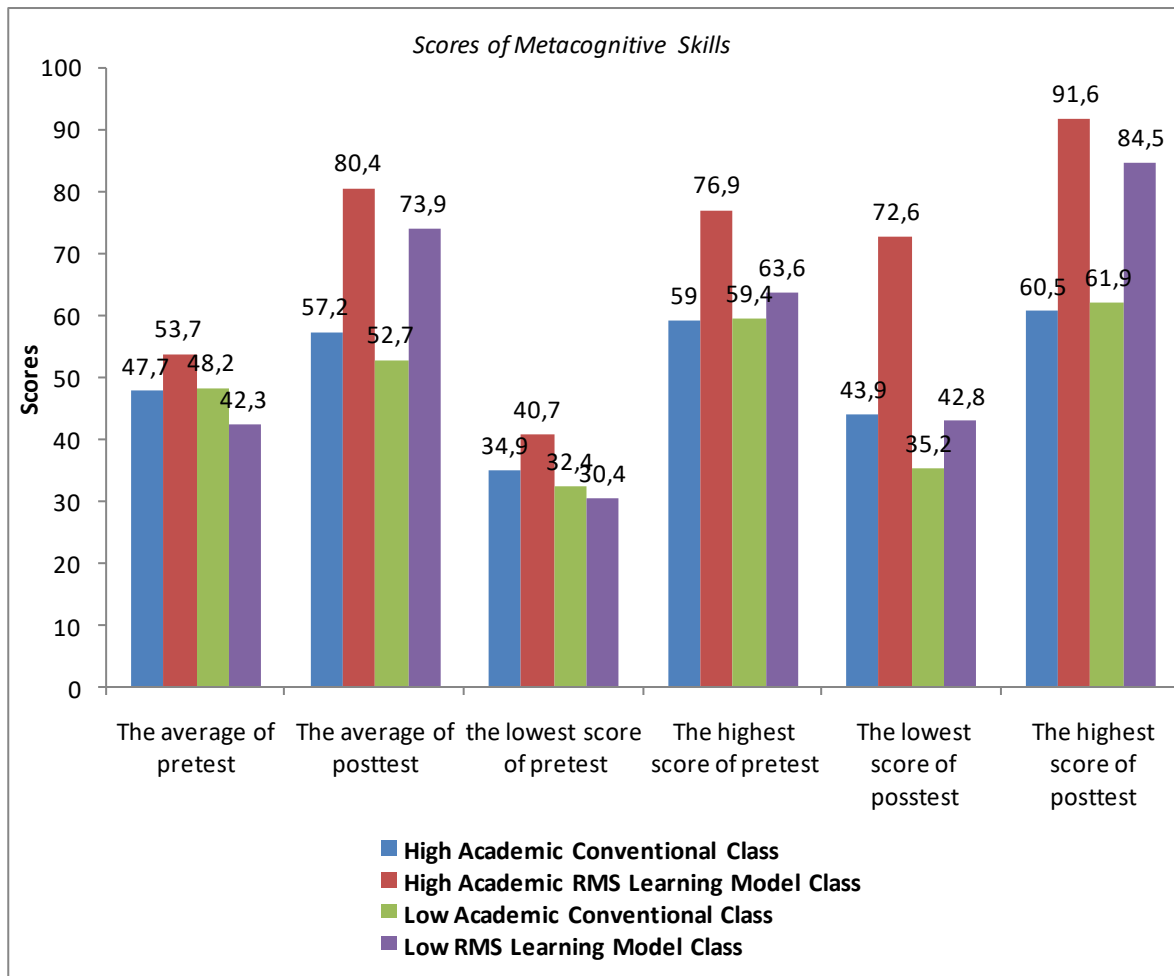


Figure 1. Summary of Metacognitive Skills Values

Scores of the RMS learning model in high and low academic students was higher than the average score of the conventional class. Metacognitive skill scores were grouped based on specific guidelines categories. determining categories based on values obtained with a range of values 88-109 (very high), 66-87 (high), 44-65 (sufficient), 22-43 (low), 0-21 (very low). Summary of the metacognitive skill scores data of pretest and posttest can be seen in Table 5.

Table 5. Summary of Metacognitive Skill Scores by Category

Class	A	Score	Category (%)				
			Very high	High	Sufficient	Low	Very low
Conventional	HA	Pretest	0	0	80	20	0
		Posttest	0	6,7	86,6	6,7	0
	LA	Pretest	0	0	66,7	33,3	0
		Posttest	0	0	86,7	13,3	0
RMS learning model	HA	Pretest	0	12,5	75	12,5	0
		Posttest	12,5	87,5	0	0	0
	LA	Pretest	0	6,2	31,2	62,6	0
		Posttest	0	87,6	6,2	6,2	0

Notes: A: Ability
 HA: High Academic
 LA: Low Academic

Table 4 shows the percentage of pre-test score in conventional and RMS learning model class for both high and low academic students was low enough. At the posttest, metacognitive skill score increased in both classes. After the implementation, conventional class was still dominated by the sufficient and low metacognitive skill category, but 6.7% in the high category. Unlike RMS learning model class for the high and low academic students was dominated by high metacognitive skill criteria, even 12.5% in the “very high/excellent” at high academic achievers. This information proves that compared to conventional classroom, RMS learning model was able to more enhance metacognitive skills. Result of the essay test data based on indicators of metacognitive skills can be seen in Figure 2.

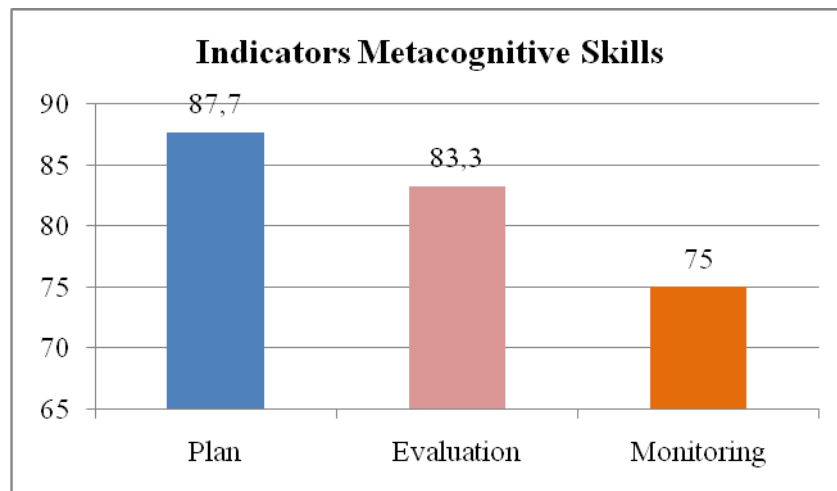


Figure 2. Summary of Indicators Metacognitive Skills Values

Figure 2 indicates that the highest indicator of metacognitive skill based on the test result was plan indicator, whereas the lowest was monitoring. It indicates that RMS learning model was more capable in improving the skill of students in learning planning including self-management in learning readiness and learning process in class. Description of each metacognitive skill indicators can be seen in Table 6.

Table 6. Value (%) Metacognitive Skills Based Indicators

No	Indicator	Description	Score (%)
1.	Plan	• Setting goals	90
		• Enabling relevant resources	80
		• Choosing the right strategy	70
2.	Evaluation	• Determine the level of understanding of a person	85
		• How to choose the right strategy	80
3.	Monitoring	• Checking one's progress	85
		• Choose the appropriate improvement strategies when the chosen strategy does not work.	70

Table 5 explains that the highest metacognitive skill of students was in the skill of determining learning goals in studying a topic of material to be studied. The lowest cognitive skill was on choose the appropriate improvement strategies when the chosen strategy does not work. It gives explanation that RMS learning model could optimally improve the metacognitive skill of students in every description of metacognitive skill indicator. The determination of students' learning goals in learning model was facilitated in the step of reading that is intriguing the students on the material studied and what will be studied. Students' metacognitive skill related to the selection of strategy was weak in comparison to

other description. Thus an emphasis was needed on the weakness during the learning process with RMS learning process.

The process of learning in class using RMS learning model was observed in each learning meeting by the observers who are also the researchers. The result of the appraisal indicates that the average value was 4.90. It can be interpreted that the learning model syntax had been well conducted and all syntax has been done. The result of the appraisal of Learning Model Worksheet from observer is displayed as follow. Description of process of RMS learning activities can be seen in Table 7.

Table 7. *Process of RMS Learning Activities*

No	Appraisal Aspects	Average Value
1.	Introduction	4,90
2.	Main activities	4,90
3.	Closure	4,90
4.	Time management and class atmosphere	4,90
Total average		4,90

There were differences in activities conducted by students in experimental and control groups, especially in terms of student liveliness. The students in experiment class were very active since the class demanded individual and group activities and the students were facilitated with interaction among the students.

Results about the metacognitive skills based on the observation sheet that 1) students know the group members, 2) students are confident and serious in carrying out discussions, 3) student punctual in collecting tasks, 4) the student is able to define the objectives and strategies of learning, 5) the student is able to provide an evaluation on himself/herself and others.

The metacognitive skills data analysis using ANCOVA preceded by the assumption that, 1) the data normality test conducted by One Sample Kolmogorov-Smirnov test and 2) test of homogeneity of variance using the Levene test. The results showed the normal distribution of data where metacognitive skills score in both conventional class and in RMS learning model class was greater than 0.05 it was equal to (0.200 and 0.088). Homogeneity test by using Levene test showed that metacognitive skills data of conventional class and RMS model class has greater score than or equal to 0.05. It was equal to 0,05.

ANCOVA test with pretest as covariant was done to see whether there was an effect of RMS learning model and academic ability as well as its interaction to students' metacognitive skills. The summary of ANCOVA test of the treatment effects to the students' metacognitive skills can be seen in Table 8.

Table 8. *Summary of ANCOVA Test Results of Treatment Effects to Metacognitive Skills*

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	9182.879 ^a	4	2295.720	49.186	.000
Intercept	3000.590	1	3000.590	64.287	.000
Pretest	1060.551	1	1060.551	22.722	.000
Learning Model	7618.759	1	7618.759	163.231	.000
KA	99.331	1	99.331	2.128	.150
Learning Model * KA	57.993	1	57.993	1.242	.270
Error	2660.451	57	46.675		
Total	285092.620	62			
Total Corrected	11843.330	61			

In Table 8, the test results for the learning sources model had F value of 163.231 with a p-value less than α ($p \leq 0.05$) in which significance value is 0,000. It indicated that there was a difference between the students' metacognitive skills taught using RMS model and taught using conventional learning models. Based on this reason, it can be concluded that there was significant effect of RMS learning model to students' metacognitive skills.

The next test determined whether there was the effect of academic ability to students' metacognitive skill, based on test results. In Table 6, the source of academic skills had F value of 2.128 with a p-value greater than α ($p \geq 0.05$) in which significance value is 0.150. It means that there was no effect of academic ability to students' metacognitive skills. So, there was no significant effect of the academic ability to students' metacognitive skills.

The next test examined whether there was any effect of the interaction of learning model and academic ability to the students' metacognitive skills. Based on test results in Table 6, the source of the interaction model of learning and academic skills had F value of 1.242 with a p-value greater than α ($p \geq 0.05$) with 0,270 significance. It means that there was no interaction effect of learning model and academic ability to the students' metacognitive skills. So, there was no significant effect of interaction of learning model and academic ability to the students' metacognitive skills. The mean value of corrected and improved metacognitive skills is in Table 7. RMS learning model class and conventional learning class obtained corrected values metacognitive skills and different upgrade. The impact of RMS learning model was 51,5% higher than conventional model on metacognitive skills.

Table 9. *The Mean Value Corrected Metacognitive Skills*

Learning Model	Mean Corrected		Enhancement (%)
	Pretest	Posttest	
Conventional	47,9	54,9	14,6
RMS Learning Model	46	76,4	66,1

DISCUSSION and CONCLUSION

The results of data analysis revealed that the students' metacognitive skills who taught through using RMS learning model was better than the students who taught through using conventional learning models. The indications of increasing metacognitive skills in the RMS learning model classroom based on observer's field notes such as students were able to demonstrate the purpose of their learning, students were able to monitor progress in learning by knowing the things that have been understood or not understood, and the students were able to correct the errors in learning by finding additional relevant learning resources.

The RMS learning model has reading syntax, mind mapping, and sharing. In *reading* activities, students should individually read variety of sources regarding material or studied topics. The students were required to be able to define the main idea, purpose, and determine the things they are understood yet. Reading text material or a specific topic will trigger them to ask their selves if any shortcomings or something that they cannot understand. So, it will evoke their motivation and curiosity to find the answers by searching information from various sources. This activity can improve metacognitive skills that can be used to plan, monitor, and evaluate the successes learning. According to Amzil (2013), results of research on reading activity is able to improve the evaluation. Vehovec et al (2014) stated that reading can improve metacognitive skills.

The next student performed activities were individual mind mapping and collaborative group. These activities allowed students to think analytically, manage the information, and linking one concept to another in order to construct the previous obtained concepts in written mind maps. Creating mind map activity potentially be able to assist the student to plan, monitor,

and evaluate or correct the results of a mind map. So, students' metacognitive skill will increase. This is in line to Adodo (2013) research that mind mapping activity can improve self-regulation of the learning progress. Similarly, it was stated that learning by using mind map can enhance students' activity that spurs their creativity so that learning goals can be achieved (Zubaidah et al., 2017).

Social interaction occurred in collaborative groups. The mind mapping and sharing activities were also be the factor in increasing students' metacognitive skills. The demand for collaborative mind mapping activities made the students be able to plan the necessities for a given task (Wu et al., 2013). The social interaction required the students actively involving in problem solving together, expanding thinking process, and increase the confidence. It supports research by Jayapraba & Kanmani (2013) that cooperative learning can improve every learner activation role in solving the problem together. According to research of Chua et al. (2011), collaborative learning can improve a person's self-confidence by increasing metacognitive skills.

The test results of academic ability to students' metacognitive skills showed that there was no significant effect of academic ability to students' metacognitive skills. In line with results of the research by Palennari (2011) that the academic ability does not affect the learners' metacognitive skills. And, the low academic ability can improve student metacognitive skills if they provided the orderly learning according Basith (2012).

Equitable metacognitive skills in academic ability differ from RMS learning model due to the readiness of the students in following study which already arranged by reading the preliminary information from variety of learning sources and social interaction that occur through working in collaborative group, heterogeneous group distribution, peer tutorials, and *sharing*. All students were responsible for their learning progress in individual and in a group, assisted each other in achieving learning goals. So, the equalization target was evenly distributed for each individual metacognitive skill.

The interaction of learning model and academic ability indicated that there was no significant effect between them. It provided information that the same metacognitive skills achievement among the high and low academic students after participating in learning with RMS model. The results of this study support finding of Palennari (2011) that the academic ability had no effect on metacognitive skills. This was due to the RMS learning model activity required students to be actively involved as individual from finding the information, critical and comprehensive understanding of information, pouring the mind map in *mind map*, and presenting it in the class. Aktamis, et al., (2016) and (Saglam & Sahin, 2017) states that learner's active involvement is able to enhance learning achievement.

Those activities sharpen the students' metacognitive skills for both high and low academic ability students. Every individual should be aware of learning goals, identify strategies to be able to complete the assigned task, and evaluate the learning process so that each individual metacognitive skill can be improved. It supports research of Kirmizi (2015) that the activity which demands self-learning will make students find the purpose in their learning and be able to set their learning objectives. In line with Ramdiah (2013) research that the activities that facilitate students to make decisions on any action, monitoring, and evaluating the learning process can improve metacognitive skills.

The other causes that effects equity of metacognitive skills was RMS learning model that facilitate collaborative group consist of heterogeneous members (academic high, middle, low). Cooperative learning can be a supporting way of improving learners' academic levels (Bilgin, et al., 2016). This meant that an interaction of mutual aid in the learning without reducing the individual responsibility on successful learning. The active involvement of each individual in the group study allowed thinking process of each member in solving a problem that helped students to organize the thoughts, ideas or information which required in solving a

problem. This is consistent with research of Damsa (2014) that the collaboration can improve thinking skills in problem solving. According to Long & Carlson (2011) opinion, learning to optimize the process of thinking will help learners to regulate and control their learning so it improves metacognitive skills.

The following conclusions can be derived based on the data analysis and presented discussion:

- 1) There was an effect between RMS learning model and students' metacognitive skills.
- 2) There was no significant effect between students' academic ability and students' metacognitive skills.
- 3) There was no effect of interaction between RMS learning models and different academic abilities toward the students' metacognitive skills.

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Natural Products Laboratory Project: Isolation and Structure Elucidation of Piperin from *Piper nigrum* and Andrographolide from *Andrographis paniculata*

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ABSTRACT

This study aims to review the implementation of a project-based laboratory in a natural product chemistry course in order to isolate secondary metabolites from medicinal plants. Various studies on the isolation and structure elucidation of secondary metabolites can be used in natural products laboratory project. Students are directed to study literature related to secondary metabolites isolation and structure elucidation procedures. Furthermore, students practice skills of extraction, fractionation, purification, and structure elucidation of secondary metabolites. Once students have an understanding of secondary metabolites isolation and structure elucidation procedure, they were asked to design the isolation procedure of secondary metabolites. In addition, students implemented their own design to isolate secondary metabolites. This study used a quasi-experimental research. Data was collected done through observation and qualitatively analysis was conducted on the collected data. Participants in this study comprised 32 third-year students from the chemistry education department at one of the state universities in West Nusa Tenggara, Indonesia. Participants were divided into eight groups. Each group worked on one plant sample that comprised roots of *Artocarpus heterophyllus*, fruit of *Piper nigrum*, rhizome of *Curcuma xanthorrhiza*, rhizome of *Kaempferia pandurata*, rhizome of *Curcuma aeruginosa*, rhizome of *Kaempferia galanga*, fruit of *Cassia grandis*, and seeds of *Cassia grandis*. In this laboratory project, two groups succeeded in structural elucidation of their isolated secondary metabolites, piperin (1) from *Piper nigrum* and andrographolide (2) from *Andrographis paniculata*.

Keywords: Project-based laboratory, natural product chemistry, secondary metabolites.

INTRODUCTION

Various studies have isolated secondary metabolites of biodiversity in the world (Hakim, et al., 1999; Thompson, et al., 2016). These studies could be useful in natural product laboratory project. The secondary metabolite isolation procedures of the various studies can be used as references in this laboratory project. The purpose of this laboratory activity is first to provide third-year students from the chemistry education department with the experience to design laboratory activities in order to isolate secondary metabolites from medicinal plants. Second, the



students learn the essential skills required to perform the extraction, fractionation, purification, and structural elucidation of secondary metabolites from medicinal plant. Many of secondary metabolites that can be isolated from Indonesian biodiversity showed interesting biological activities such as cytotoxicity (Blair, et al., 2013; Kardono, et al., 1991; Syah, et al., 2004), antimalarial (Linn, et al., 2005; Elfahmi, et al., 2006; Angawi, et al., 2009; Zainuddin, et al., 2007), antiviral (Handayani, et al., 1997; Kosela, et al., 2000), antifungal (Nakazawa, et al., 2007; Yasman, et al., 2003), and antimicrobial (Gu, et al., 2004). Various bioactivities show potential lead compound as useful for industrial drug or pesticide industries.

Laboratory activities that give opportunities for students to isolate secondary metabolites from medicinal plants provide an opportunity for students to prove the concept that polar compounds will be soluble in polar solvents and nonpolar compounds will dissolve in nonpolar solvents, to invent the concept such as the distribution of secondary metabolites in each species of plant, or to connect new concepts with the knowledge that has been previously owned by learners through scientific measures to rationalize various phenomena such as the properties of plants that can be used by humans for treatment. Students who understand the concept properly will be able to generalize their knowledge better than learners who just memorize definitions. Generalized capability can be used as a basis for generating original ideas (Sevim, 2013; Özdemir, 2015; Bezen, et al., 2016). These activities enhance the students' understanding of the concepts learned in class. The concepts of separation of chemical components and identification of secondary metabolite structures were difficult to learn without engaging in laboratory activities (Hakim, et al., 2016^a; Hakim, et al., 2016^b; Hakim, et al., 2016^c; Hakim & Jufri, 2017)

Reviews of Natural Product Laboratory

Much research has been conducted to improve the quality of learning of chemistry through laboratory activities (Herrington, et al., 2016; Çelik, et al., 2015; Çibik & Yalçın, 2013, Yiğit & Bilgin, 2013). Griffin (1974), in his article "Natural Products. An Independent Study Project," described natural product independent study project suitable for students in detail. This article discussed students' activities that consist of field collection and plant identification, laboratory screening procedures and isolation of large quantities, library work, and presentation of results as oral and written reports. Cannon, et al. (2001), in their study "Investigation of secondary metabolites in plants – A general protocol for undergraduate research in natural products" outlined typical experimental procedures that can be used to extract and isolate chemical constituents from a plant, suggested some simple procedures to test for selected bioactivity and explained how the molecular structures of the natural products may be determined using spectroscopic techniques. Doyle, et al. (2004) in his article entitled "Nature's Sedative: Isolation and Structural Elucidation of Valtrate from *Centranthus ruber*" exposed variety of chromatographic techniques employed in the isolation of Valtrate from *Centranthus ruber* for the college students of chemistry laboratory. Douglas, et al. (2007), in their research "Detection and Quantification of Valerenic Acid in Commercially Available Valerian Products," described that several valerian-containing products sold in pharmacies were evaluated to verify the content of *Valeriana officinalis* by identifying the presence of valerenic acid. Halpin, et al. (2010) allowed students in his article "Nature's Anti-Alzheimer's Drug: Isolation and Structure Elucidation of Galantamine from *Leucojum aestivum*" to follow the isolation procedure of galantamine from *L. aestivum* for students accessing chemistry laboratory.

Walsh, et al. (2012) in his research "Nature's Migraine Treatment: Isolation and Structure Elucidation of Parthenolide from *Tanacetum parthenium*" afforded the student opportunity to follow the entire procedure of parthenolide isolation from *T. parthenium*. Nazri, et al. (2012) reported his study "Nature's Cholesterol-Lowering Drug: Isolation and Structure Elucidation of Lovastatin from Red Yeast Rice-Containing Dietary Supplements" that explained the procedure for isolation and structure elucidation of lovastatin from red

yeast rice. Carroll, et al. (2012), in his article “Nature’s Chiral Catalyst and Anti-Malarial Agent: Isolation and Structure Elucidation of Cinchonine and Quinine from *Cinchona calisaya*,” explained various techniques in the extraction, isolation, and purification of medicinally important natural products from the crude plant material. Hakim, et al. (2016), in his article “Making a Natural Product Chemistry Course Meaningful with a Mini Project Laboratory,” afforded the student to the project isolation secondary metabolites from medicinal plant.

METHODS

This study used a quasi-experimental research. Participants in this study consisted of 32 third-year students (teacher preparation) from the chemistry education department at one of the state universities in West Nusa Tenggara, Indonesia. Participants were divided into eight groups (4 participant per group). The division of students into groups was done considering the heterogeneity of the results of the precondition test. Each group worked on one plant sample. Students follow the steps initiated in project-based laboratory that begins with a problem to be solved by the students (Hakim, et al., 2016^a), the problem being “How can I isolate secondary metabolite from medicinal plant?” Plant samples used in experiment class consisted of roots of *Artocarpus heterophyllus*, fruit of *Piper nigrum*, rhizome of *Curcuma xanthorrhiza*, rhizome of *Kaempferia pandurata*, rhizome of *Curcuma aeruginosa*, rhizome of *Kaempferia galanga*, fruit of *Cassia grandis*, and seeds of *Cassia grandis*. The plant samples were selected based on factor local herbs popularly and the existence of major compounds in the plant. The structure of project-based laboratory project can be seen in Table I (Hakim, et al., 2016^a).

Table I. Structure of Project-Based Laboratory

Component	Description
Introduction	<ol style="list-style-type: none"> 1. An explanation of the research and the schedule 2. Precondition test performance (diagnostic tests to determine the basic understanding of the chromatographic and spectroscopic techniques. For example, students understand how to interpret NMR spectra).
Laboratory activities training	<ol style="list-style-type: none"> 1. Formation of groups based on the results of the precondition test (4 students per group). 2. Lecturer discussed concepts that had a high percentage of wrong answers on the preconditions test. Students practiced in groups to isolate a secondary metabolite from the rhizome of <i>Curcuma longa</i>. 3. Lecturer and assistants provided guidance to students about the procedures to isolate a secondary metabolite from the rhizome of <i>Curcuma longa</i>.
Orientation problem	<ol style="list-style-type: none"> 1. Students were given the problem. 2. Each group worked on one plant sample. 3. Lecturers explained about mini project laboratory that had to be carried out.
Designing laboratory activities	<ol style="list-style-type: none"> 1. Students undertook a literature review of various sources and made project proposals. 2. Lecturers acted as facilitators and provided time to receive questions from students.
Presenting laboratory	<ol style="list-style-type: none"> 1. Students communicated proposals to the other groups. Communication was done through a presentation.

activities proposal	2. Students from other groups obtained information about procedures to isolate a secondary metabolite from the investigated plant sample and posed some questions or gave suggestions about the proposal for improvement. Lecturers acted as facilitators of the various problems that arose during class discussions.
Implementation of laboratory activities	1. Students implemented the proposal and collected data from sample preparation, extraction, fractionation, purification and structural elucidation of secondary metabolites. 2. Lecturer acted as facilitator in addition to guiding the investigation.
Results reporting & presentation	1. Students made a project report of their investigation 2. Students communicated their project report to other groups. Communication was done through presentations. 3. Students from other groups obtained information and posed some questions or gave suggestions about the project report for improvement. Lecturers acted as facilitators of the various problems that arose during class discussions.
Evaluation of the laboratory activities	1. Students evaluated the laboratory activities that have been performed. Evaluation of the laboratory activities carried out by assessing their own procedures and giving the corrective solutions.

The goal of the project is to design laboratory activities in order to isolate secondary metabolites from medicinal plants. Implementation of laboratory activities took place during the second semester of the academic year 2015–2016. The laboratory sessions were held for 180 min every week for an entire semester (16 weeks). In the experiment class, two secondary metabolites, piperin and andrographolide, isolated by the groups investigating *Piper nigrum* and *Andrographis paniculata* are discussed. Six secondary metabolites isolated by other groups are not discussed because the structure of these compounds could not be identified.

RESULTS and DISCUSSION

All groups have implemented their own design of laboratory activities but only two groups succeeded in structural elucidation of their isolated secondary metabolites. The difference between successful and failed groups' laboratory designs was the complexity of its isolation procedures. In general, the design of secondary metabolite isolation procedures of the failed groups is more complex than the successful groups. The differences were also seen in the characteristics of the group in that successful group has very active characteristics, while the failed group has less active characteristics.

This laboratory project trained the students who have not experienced isolation of secondary metabolites. So, we choose herbs for which the active constituent is already known. It also confirmed that the students' failures were not because of the herbs used in the research. The fact that the active constituent was already known does not necessarily make the exercise of finding the isolation procedure easy for the student. It happened because the students were asked to develop a procedure that has been designed in accordance with the results of each stage of isolation process. This laboratory is useful for third-year undergraduate students who have a basic understanding of the chromatographic and spectroscopic techniques used in the identification of natural compounds. Many activities in this laboratory may be appropriate for other courses such as structure elucidation of organic compounds course and organic chemistry course.

Piperin (1) was successfully isolated by the group investigating *Piper nigrum*, and andrographolide (2) was isolated by the group investigating *Andrographis paniculata*. Structure of piperin (1) and andrographolide (2) can be seen in Figure 1. Other groups failed to identify

the structure of the isolated secondary metabolites due to less pure isolated compounds. Although the majority of the student groups failed to isolate a secondary metabolite that could be characterized, they still have gained experience in designing laboratory activities and conducting isolation of secondary metabolites.

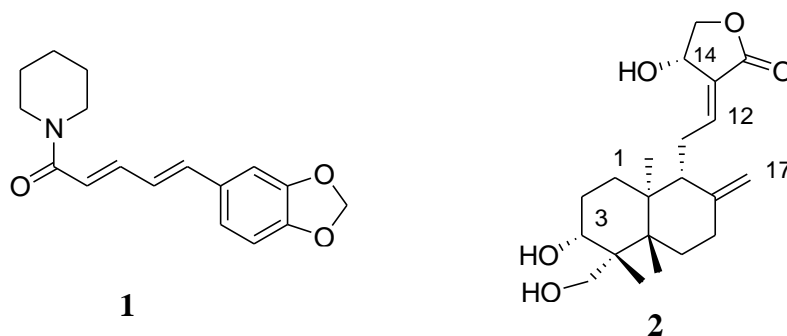
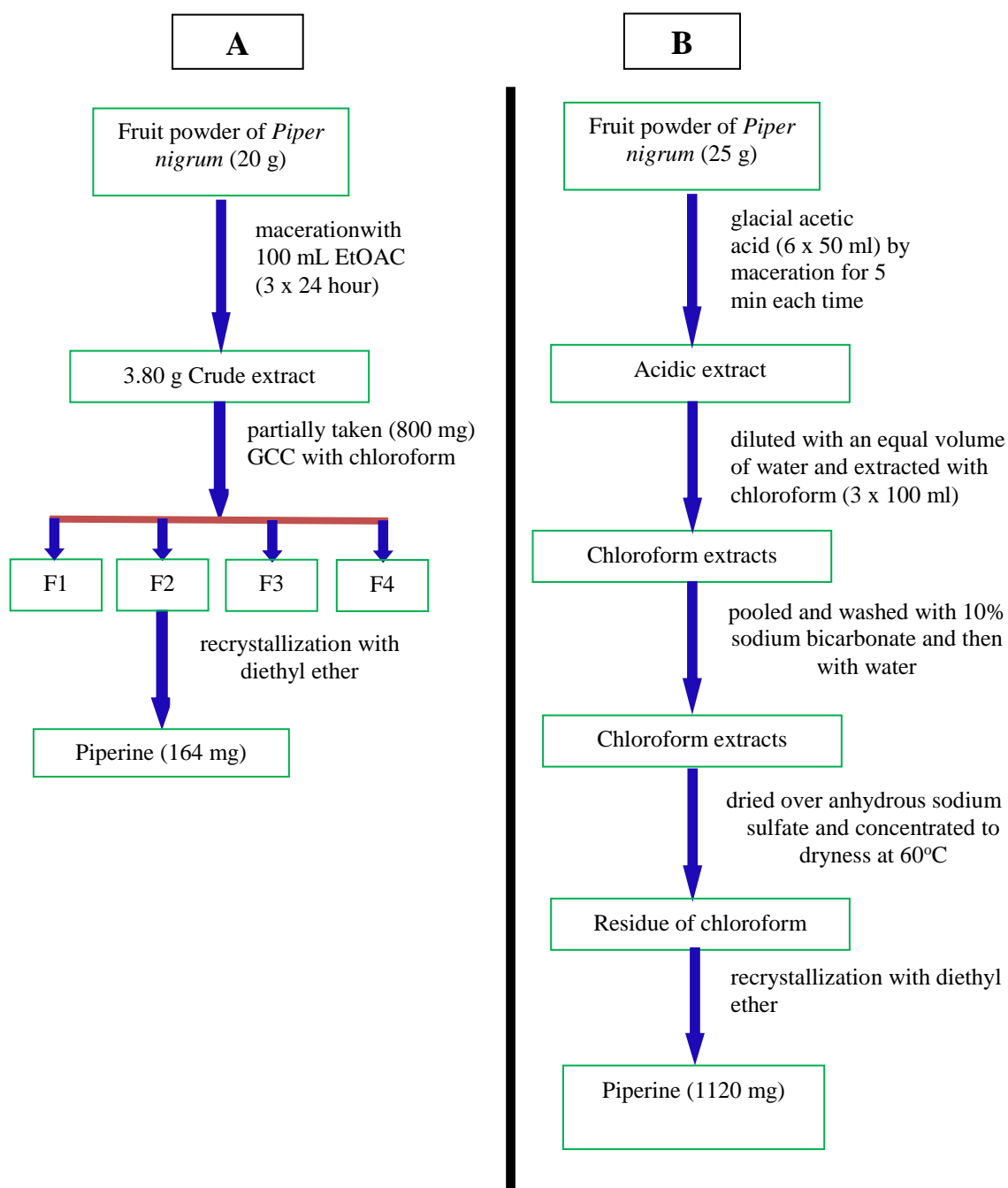


Figure 1. Structure of piperin (1) and andrographolide (2)

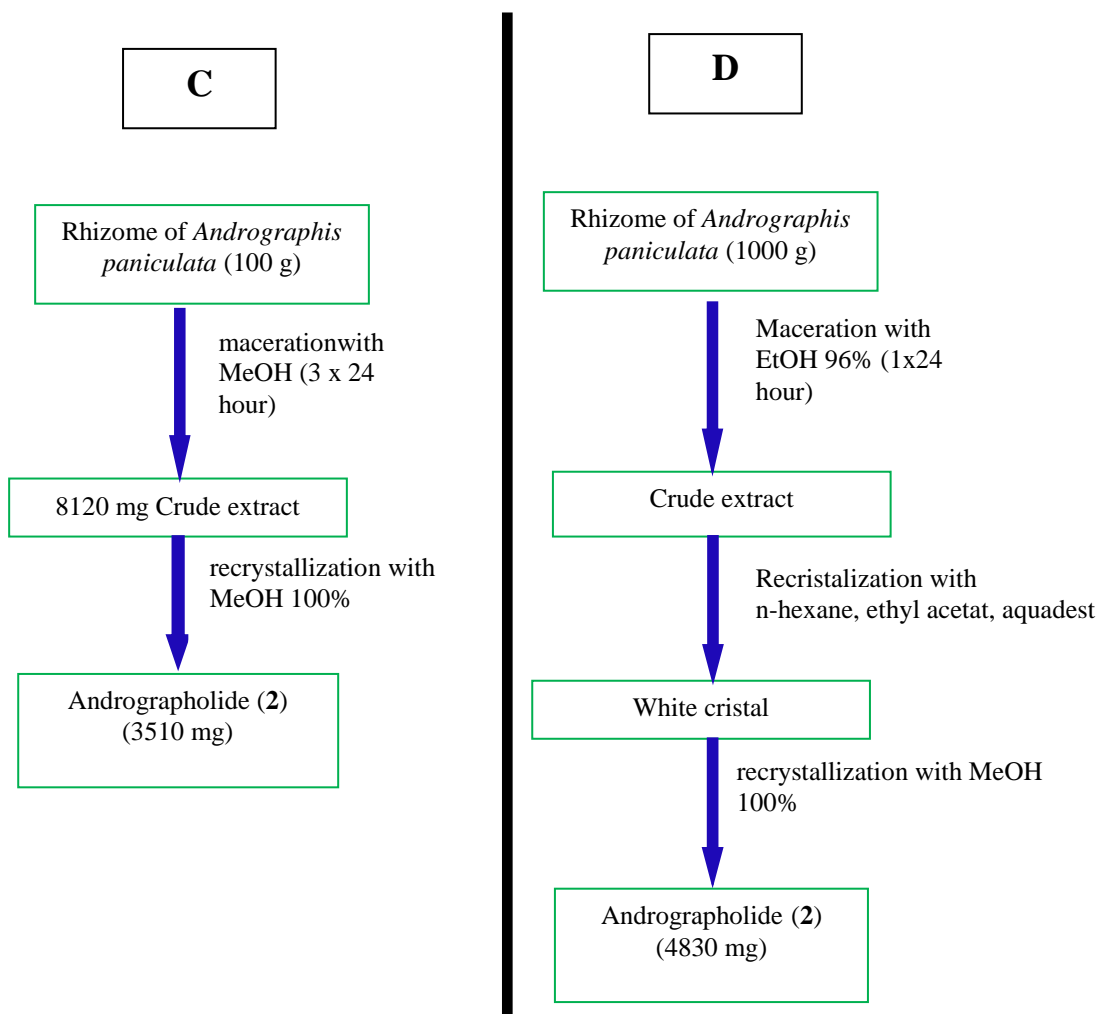
The students' group investigating *Piper nigrum* extracted fruit powder of *Piper nigrum* (20 g) with 100 mL ethyl acetat during 3 x 24 hours, and 3.8 g of crude extract was produced from these extraction processes. Furthermore, students partially took 800 mg of crude extract of *Piper nigrum* for Gravity Column Chromatografi with chloroform as eluent. Four main fractions resulted from this fractionation. Fraction 2 was purified with recrystallization using diethyl ether as solvent. Piperine (164 mg) was successfully isolated by students. These procedures were different from those in the literature (Kanaki, et al., 2008), as shown in Figure 2. It happened because the students were asked to develop a procedure that has been designed in accordance with the results of each stage of the isolation process.



A = Students' group investigating fruit of *Piper nigrum*, B = Literature (Kanaki, et al., 2008)

Figure 2. Procedures to isolate piperin from Fruit powder of *Piper nigrum*

Similarly, the students' group investigating *Andrographis paniculata* also produces a different procedure than there is in the literature (Warditiani, et al., 2012), as shown in Figure 3. Rhizome of *Andrographis paniculata* (100 g) was macerated with MeOH during 3 x 24 hours to produce 8.12 g crude extract. Furthermore, the students used MeOH for recrystallization process. Andrographolide (2) (3510 mg) was successfully isolated by students.



A = Students' group investigating rhizome of *Andrographis paniculata*, B = Literature (Warditiani, et al., 2012)

Figure 3. Procedures to isolate Andrographolide from rhizome of *Andrographis paniculata*

SUMMARY

This laboratory project has given the students a chance to experience being a scientist as well as an opportunity to solve project problems using scientific measures. This laboratory can help students with active characteristics to be successful, but it has also hindered students with passive characteristics from being successful. The students have designed laboratory activities and gained firsthand experience of isolating secondary metabolites from medicinal plants. Two of the eight groups succeeded in getting the pure compound. Both groups produced different procedures from literatures. It indicates that these laboratory activities enabled students to develop original ideas.

SUPPLEMENTAL MATERIAL

UV, IR, and NMR spectra of piperin (1) and andrographolide (2) are available in appendix.

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Appendix

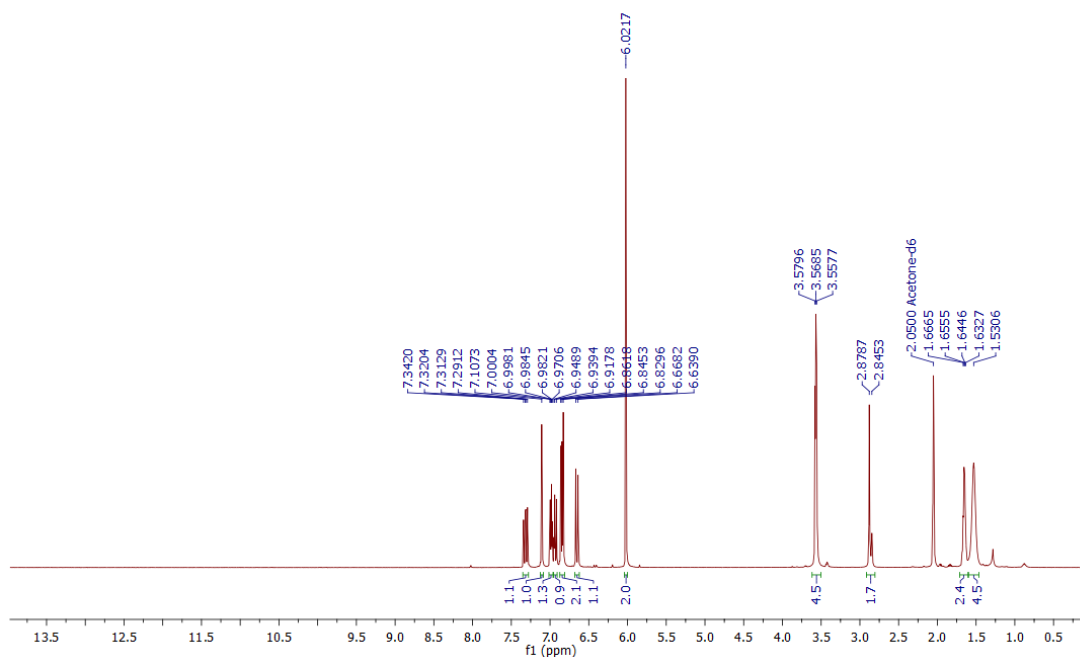
A Natural Products Laboratory Project: Isolation and Structure Elucidation of Piperin from *Piper nigrum* and Andrographolide from *Andrographis paniculata*

Aliefman HAKIM¹ and A. Wahab JUFRI²

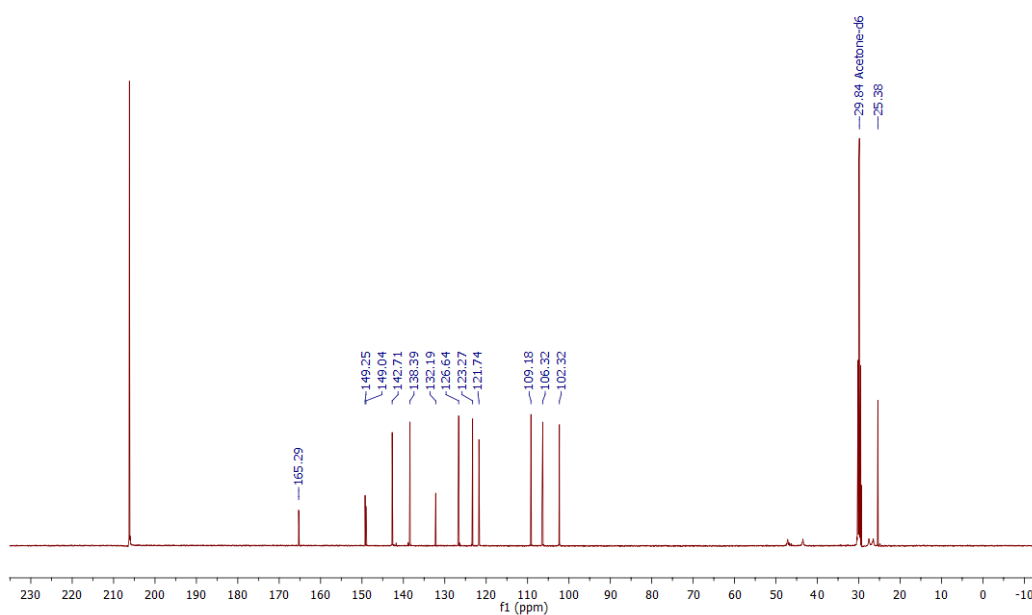
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Aliefman-mumi2_1H



Aliefman-mumi2_13C



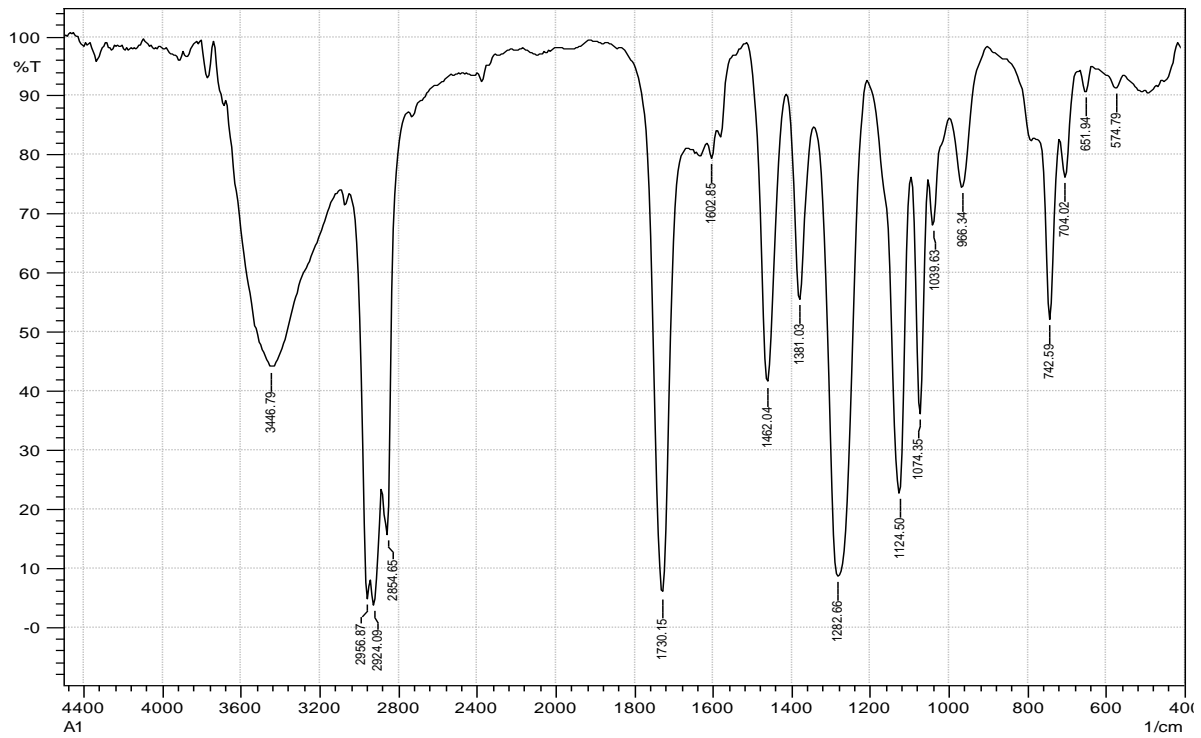


Figure 6. IR spectra of piperin

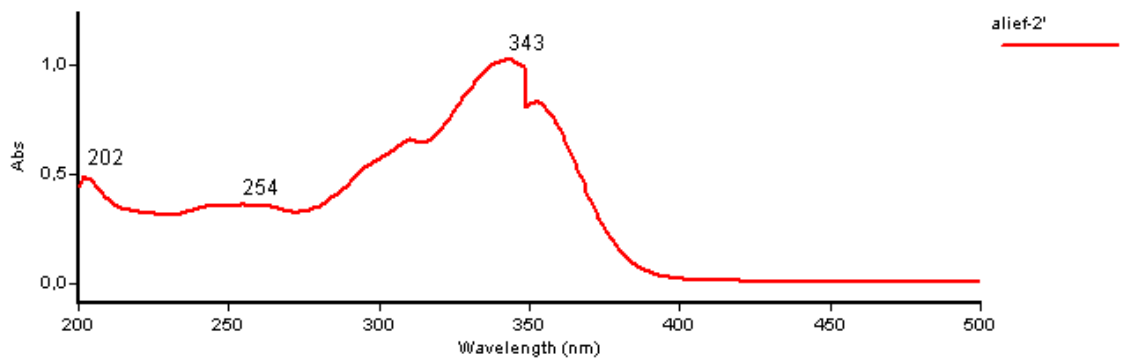


Figure 7. IR spectra of piperin

Alefman-mumi3_1H

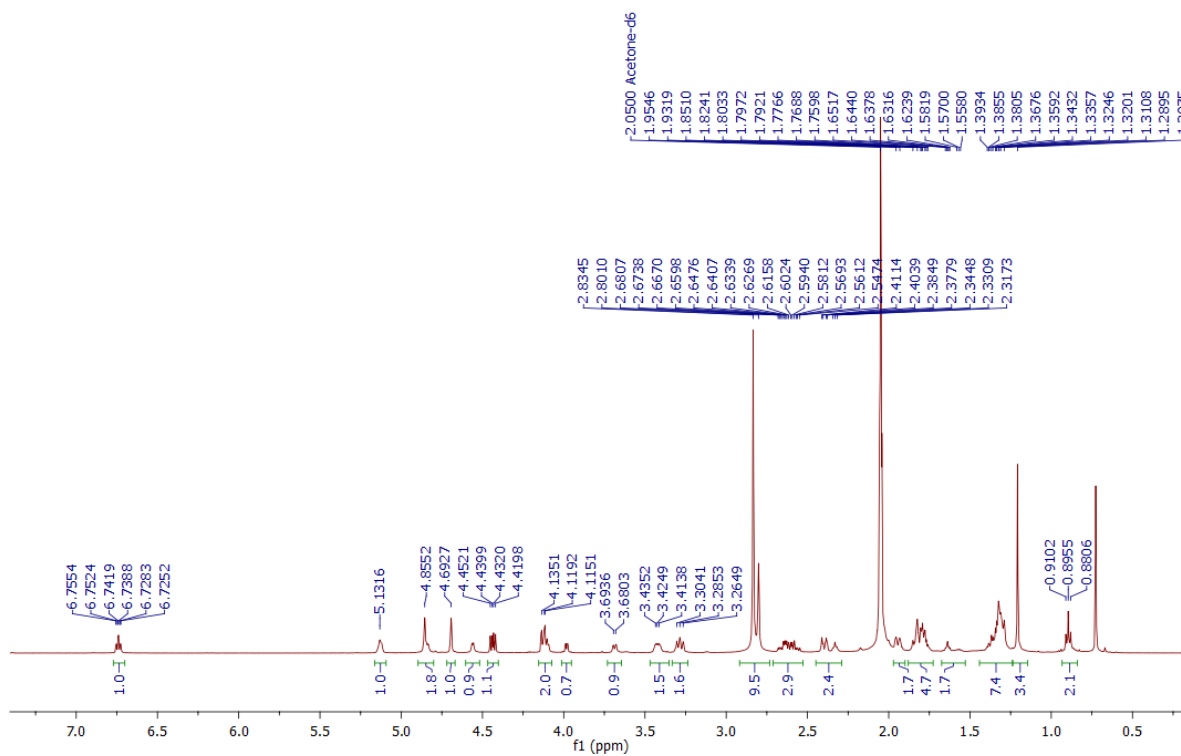


Figure 8. 1H-NMR spectra of andrographolide

Alefman-mumi3_13C

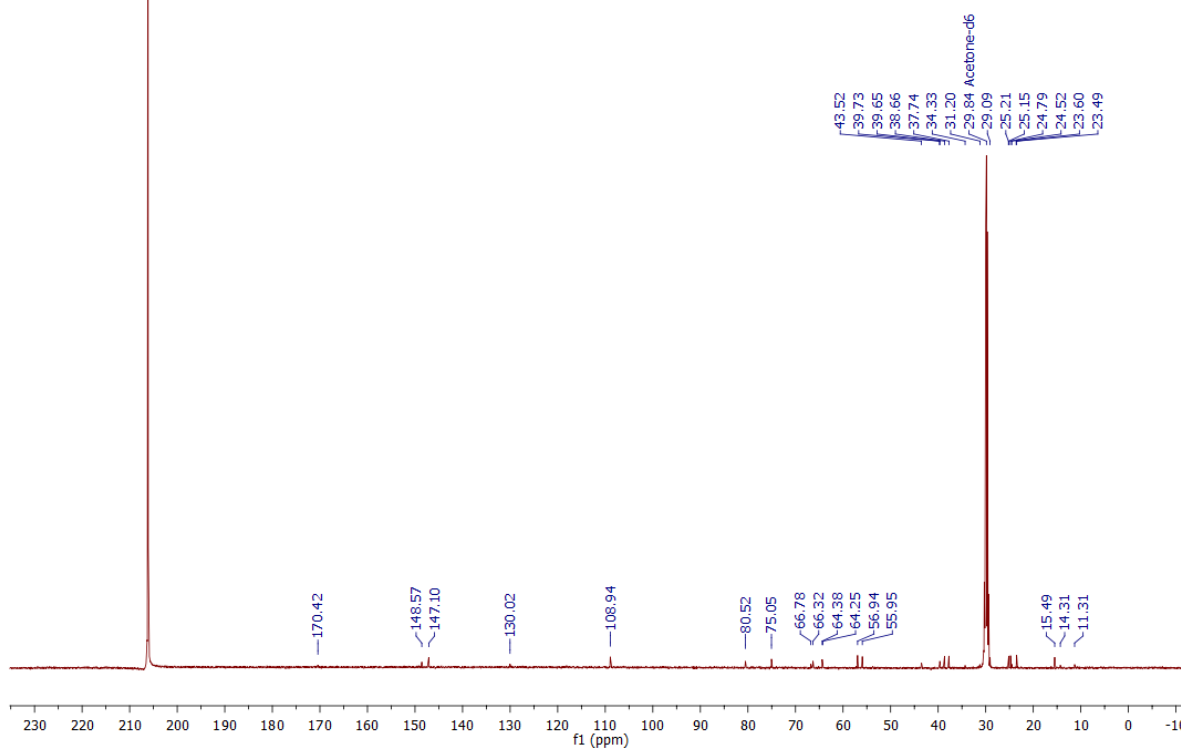


Figure 7. 13C-NMR spectra of andrographolide

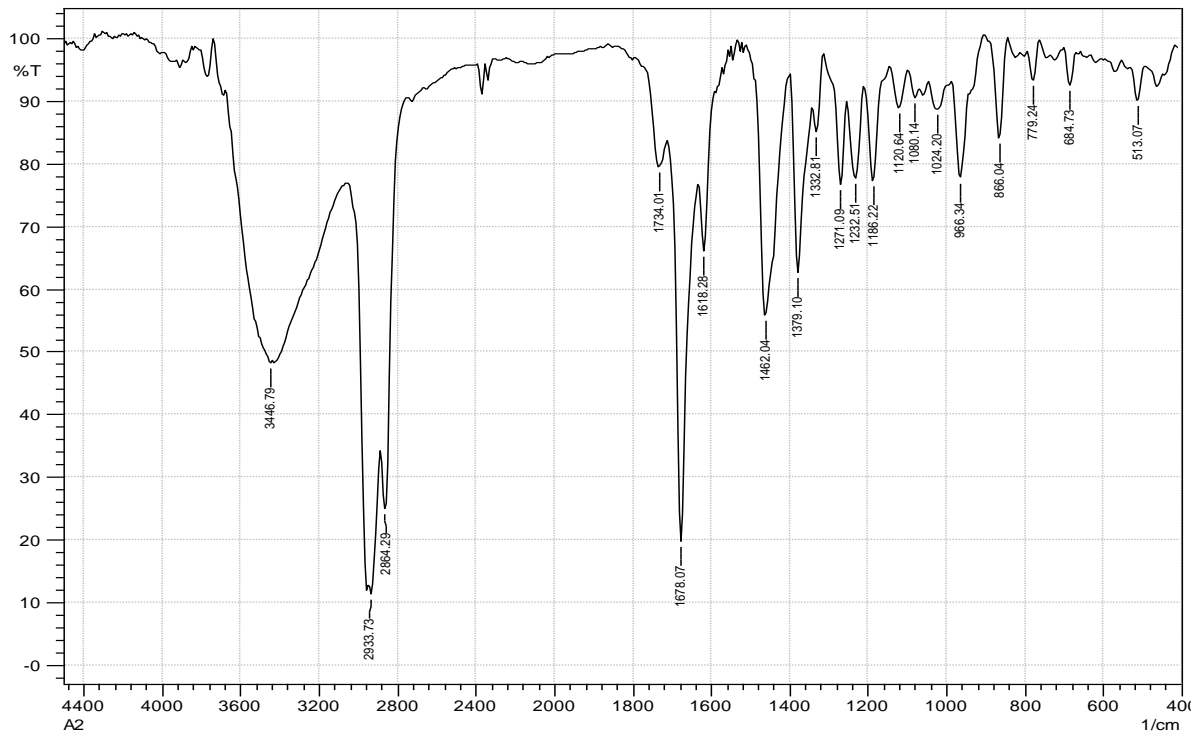


Figure 9. IR spectra of andrographolide

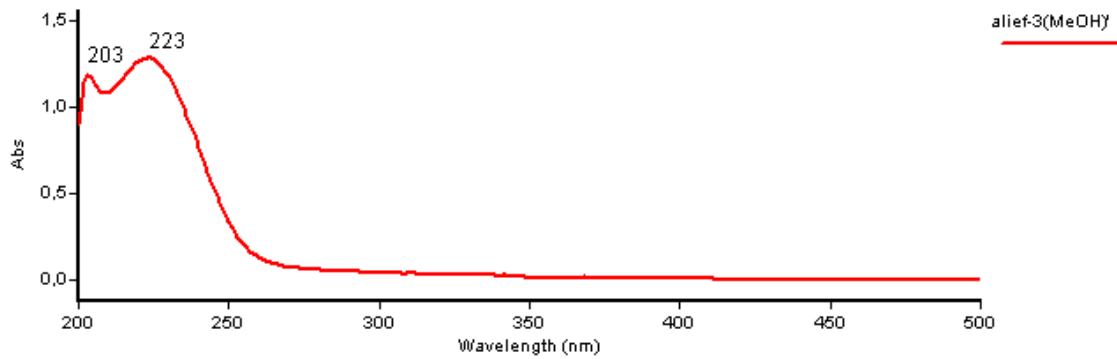


Figure 10. UV spectra of andrographolide

Vernacular Misconceptions in Teaching Science – Types and Causes

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ABSTRACT

The aim of this study was to identify, classify and describe different types of vernacular misconceptions assessed with the items used in a study named *Laboratory of Thinking*, Diagnosis of Science Education in Poland. We provide an outline of contemporary conceptual change theories and establish a typology of misconceptions where it was distinguished as amphibological, pseudodeictic, hypernymical-hyponymical and contextual ones. The vernacular misconceptions arise when students' experience problems with the usage of certain scientific language phrases and they may appear in people of all ages, professions and backgrounds. Selected items, together with their detailed description are discussed as well as the possible influence of misconceptions on the students' learning process.

Keywords: Vernacular Misconception • Misconception • Conceptual Change Theory • Science Items • Science language

INTRODUCTION

Prior knowledge, conceptual change and misconceptions

According to Resnic (1983), one can say that students do not come to school as blank slates and have some initial conceptions that influence the didactic process. Clark (2012) pointed out that initial conceptions may be dynamic or structured, explicit or implicit. Several theories have been proposed to account for the transition from common-sense image of the world and phenomena it to a scientific understanding of them. This transition is often referred to conceptual change which can be defined as



learning in which pre-instructional conceptual structures of the learners have to be fundamentally restructured to allow students to acquire science concepts (Duit and Treagust, 2003). The notion of conceptual change may cover several meanings as exactly stated by Scott, Asoko and Leach (2007). Conceptual change can be perceived as the *process* of learning or as its *products*; it may mean *exchange* of concepts or their *modification, addition, or altering the relationships* between them. Finally, conceptual change may be seen as the *process of using strategies* to bring children's thinking in line with scientists (Agiande, Williams, Dunnamah, Tumba, 2015).

In recent years, two approaches have been prevalent related to the nature of conceptual change: the *knowledge-as-elements approach* (diSessa, 1988) and the *knowledge-as-theory approach* (Ioannides and Vosniadou, 2002). DiSessa (1988) describes conceptual change as resulting from the dynamic, mutable interaction of loose, mutually independent basic conceptions which called as *phenomenological primitives* (abbreviated *p-prims*). Vosniadou, in turn, argues for a model that postulates the existence of complex and stable theoretical structures which the learner perceives encountered phenomena. While some researchers emphasize their commonalities, these models are often strongly contrasted with each other and presented as far as deeply contradictory at least their significant instructional implications are concerned (Brown, 2010). From the implications and resulting applications, one of the descriptions of the conceptual change is the identification of the learner's prior misconceptions and "fixing" them through exchanging them or adding new conceptions that are more fruitful, plausible and intelligible (Özdemir and Clark, 2007, Chi and Roscoe 2002).

These pre-instructional conceptions have been named differently by various authors: *alternative conceptions* (Driver and Easley, 1978), *children's science* (Gilbert, Watts and Osborne, 1982), *personal knowledge* or *spontaneous knowledge* (Pines and West 1986), *misconceptions* (Helm 1980), and *preconceptions* (Clement, 1982; Clement, Brown and Zeitsman, 1989). Clement (1993) later distinguished between *preconceptions* as any prior knowledge (correct or not) and *misconceptions* as solely the sort of knowledge that is erroneous. Similarly, Skelly (1993) defined misconception as a mental representation of a concept that does not correspond to the currently held scientific theory. Therefore, misconceptions and preconceptions should be distinguished from plain and absolute lack of knowledge because the latter does not cause problems obviously addressed to conceptual change— that there is no need to undo or redo an incorrect framework which does not exist and is not widespread (Leonard, Kalinowski, Andrews, 2014). According to Page (2012), partially correct conceptions (i.e. those that are not entirely wrong and can be used in teaching) may be called as *alternative frameworks, naïve ideas, or children's ideas*.

The distinction made by Clement (1993) is going to be followed in the present article to avoid terminological confusion and the term *misconception* will only be used for those of pre-instructional conceptions that are not conform with up-to-date scientific theories. Thus, the term misconception is not actually going to refer to the misconceptions of Vosniadou's more specific view.

Walt (2011) stated that hardly anyone is certainly free of miscomprehensions, misperceptions or misjudgements that result from the usage of language. As Page (2012) says, these may be related not only to science but also to virtually all aspects of life such as religion, interpersonal relationships, history or simple housework, and may be found both in students and in teachers, regardless of their academic achievement. In a review article, Tippet (2010) stated that misconceptions may be considered as essential and unavoidable features of learning. Moreover, İnciser (2007) adds that

misconceptions display noticeable consistency throughout the populations of the world.

Misconceptions may be divided in two ways according to their origin or to their functional type. According to Skelly (1993), they may originate from personal experience and institutional instruction. The functional type can be distinguished as *non-scientific beliefs*, *conceptual misunderstandings*, *preconceived notions*, *factual misconceptions* and *vernacular misconceptions* as classified by the Committee on Undergraduate Education (1997).

Johnstone (1984), Bodner (1987) and Sirhan (2007) stated that the principal sources of misconceptions are overloading the learner's short-term memory and wrong mental strategies (teaching with the use of algorithms and hastily covering too much material). In addition, Glaser (1984), Sweller (1988) and Lukša (Lukša, Radanoviš, Garašiš, Sertiš Periš, 2016) added that problems of conceptual learning may be due to going on to problem-based activities before properly internalizing the content, standard student epistemology, sources related to prior knowledge, mismatch of the cognitive demands of the subject matter with the developmental level of the learner, or language-related problems.

Language confusion

Communication is indispensable for transferring knowledge and language has a vital importance for science literacy as a means for communication. The language is used to convey procedures, inquiries and understandings to others in the form of written and spoken communications. As Yore (2003) observes, mathematics is not the exclusive language system of science. Both in scientific research and in teaching science, other representations are useful or even necessary such as analogies, metaphors, symbolic thinking and valid terminology which is often complex. The very language of science is not to be confused with everyday speech (natural language) as it is artificial and aims at monosemy. The vocabulary used for scientific purposes differs considerably from its everyday use, where notions may have numerous and often contradictory, meanings that depend strongly upon the situation (Sirhan, 2007). Though ambiguousness and equivocality may arise as particular specialties have their idiosyncrasies, there are certain standards of communication among scientists as pointed out in the members of Association for Science Education chat summary (Association for Science Education chat summary: What misconceptions do students have in science? 22.06.2011). The discrepancy between the natural language used in everyday life and that used in science classes causes problems that significantly impede the teaching process.

A definition of the vernacular misconceptions may be made according to Page (2012) who perceives it as the result of language confusion where mistaking everyday speech lexemes for scientific terms leads to erroneous interpretation of phenomena. This sort of misconceptions is particularly interesting since it is situated somewhere in between experience-based sources and instructional ones. The study of different authors (Champagne, Klopfer and Anderson, 1980; Linn, 1980; Glaser, 1984; Green, McCloskey and Caramazza, 1985; Sirhan, 2007; Kocakulah & Kenar Açı, 2010; Ezquerra, Fernandez-Snachez, Magaña & Mingo, 2017) proved that the vernacular misconceptions stem not only from the fact that children acquire some vocabulary and (mis)representations in their childhood (at home) but also from textbooks and terminology use of teachers without being aware of different students may differently understand a concept or some students may not be able to face with the difficulties of

the subject matter content as far as the vocabulary and syntax are concerned (Çobanoğlu & Şahin, 2009).

The vernacular misconceptions include problems with vocabulary and symbols as well as analogy and metaphor used in the subject matter. One of the difficulties related to terminology in teaching and learning science is that normally a learner is supposed to acquire not only a considerable number of new words but also the whole concept behind them and how they work in a context which are often abstract and in mutual relationships. Moreover, teachers tend to overestimate ability of students to understand in addition correctly and knowingly use the vocabulary. Some of the teachers unconsciously mislead students through replacing strict scientific terms excessively by everyday speech expressions. Another issue is the multiple-level representation of symbols in science. For instance, one symbol may be used for different purposes by different disciplines or even within one discipline (e.g. the letter “N” may stand for “North” in earth science, “nitrogen” and “normality” in chemistry, “newton” in physics) whereas one concept may be represented with different symbols (e.g. “energy” that is written as “E”, “Q”, “T” or “U” etc. depending on the context).

The analogies and the metaphors may be very helpful in teaching, but sometimes they bring more problems than they solve. Einstein is believed to say that everything should be made as simple as possible but not simpler while it is often the case that metaphors conceived to make things easier are more complex than the problem itself. On the other hand, the “seductive power” of analogy makes many people neglect the important differences while underlining the similarities. This has considerable impact on language structures that are established in the way the students think and speak about the natural phenomena. The metaphors are also perceived as tools offering a link between emotion and cognition, because they encourage learners to think more creatively without stick into rigid theories (their preconceptions included). However, this is only recommendable when the metaphor helps the explanation and does not replace it.

METHODS

The studies on misconceptions of students may improve our understanding of the reasons behind the difficulties that they experience in learning science. The present paper is meant to show some of the tools used in the *Laboratory of Thinking* study and the student results achieved in it. Sources of the common vernacular misconceptions were analysed and discussed which appear both in Polish and in other selected languages. Ways of tackling this problem was suggested based on findings and on literature review. The paper focused on:

- identifying the items that assess misconceptions among those used the *Laboratory of Thinking* study,
- distinguishing the items that assess vernacular misconceptions, and
- conceiving a typology of misconceptions related to the use of language together with discussing exemplary tools that illustrate them.

a) Research designing

The long-term study *Laboratory of Thinking – Diagnosis of Science Education in Poland* has been conducted by the Science Section, Educational Research Institute, Warsaw, Poland. Its aim was to examine the level of skills and scientific knowledge of the ISCED2 level (*gimnazjum*) graduates taught according to the new science

curriculum introduced to schools in 2009. The findings of the study help to support teachers' work according to the recently changed curriculum. The study was not focused on students' misconceptions, nevertheless a part of the items used in it were clearly useful in tracking misconceptions.

Not all the items discussed in the present paper were used in the main study but only during the item preparation stage (the field trial). However, the qualitative information about misconceptions found in their results seemed so significant that it was decided to disclose them and analyse their outcome together with the items that did appear in the main study.,

b) Study group

The long-term study *Laboratory of Thinking* is composed of four cycles. From Table 1, it can be seen that over 7,000 students (having completed ISCED2 stage) were examined in the first two study cycles and in the fourth one and– another 14,000 in the third cycle (over 7,000 as in the first, second and fourth cycle and at the same time another group of more than 7,000 having completed the first year of ISCED3).

Table 1. Number of schools and students assessed during each cycle of *Laboratory of Thinking* study

No. of study cycle	1	2	3	4
Year of the study	2011 / 2012	2012 / 2013	2013 / 2014	2014 / 2015
No. of schools	180	180	180	180
No. of students	7700	7400	14000 7000	7000
Level of education	ISCED2 level	ISCED2 level	ISCED2 level	After 1st year of ISCED3 level ISCED2 level

The student samples were random and representative. For example, they reflected the proportions of students in the three types of schools in Poland (Table 2).

Table 2. Different kind of schools at ISCED2 and ISCED3 level in terms of shortened characteristics of the educational stages in Poland

Polish term	ISCED level	grade numbers	students' age	English term
Gimnazjum	2	7, 8, 9	13-15	lower secondary school
Liceum ogólnokształcące	3	10, 11, 12	16-19	secondary general school, comprehensive secondary school
Technikum	3	10,11,12	16-20	secondary technical school
Zasadnicza szkoła zawodowa	3	10,11,12	16-19	secondary vocational school

The sample consisted of 180 upper secondary schools and was stratified with respect to the type of school (basic vocational, technical secondary or comprehensive secondary), the capacity of the school (number of students in the first grade), the location of the school (countryside, town under 5,000, city 5,000–100,000 or city over 100,000 inhabitants), female to male student proportion (over 80% boys, over 80% girls or balanced) and whether being a state-operated or a private school.

c) Data Collection Tools

In each cycle of the study (year by year) a paper-and-pencil test was composed of 208 items that were used in each of the four science subjects (chemistry, physics, biology, and geography). 52 items were included for each of the subjects. About 60–80% of them were linking items, i.e. items that are repeated every year, and thus have to remain confidential. The items were arranged in 16 test versions in a way that both the difficulty level and the time needed to solve each version were similar.

Data collection tools for the study were prepared during workshops organized by the Institute of Philosophy and Sociology, Polish Academy of Sciences, in the years 2008–2010. The items were conceived individually by specialists from specific science groups (biology, chemistry, physics, and geography group), and then in several science groups of several people each headed by a subject leader.

The item preparing process (Figure 1) involved multiple reviews by academic specialists and a field trials performed on random student groups as well as interviews using the cognitive laboratory assessment (verbal probing technique as described by Willis, 1999), when needed. Details of the methodology can be found in the *Laboratory of Thinking* extensive study final report (IBE, 2012).

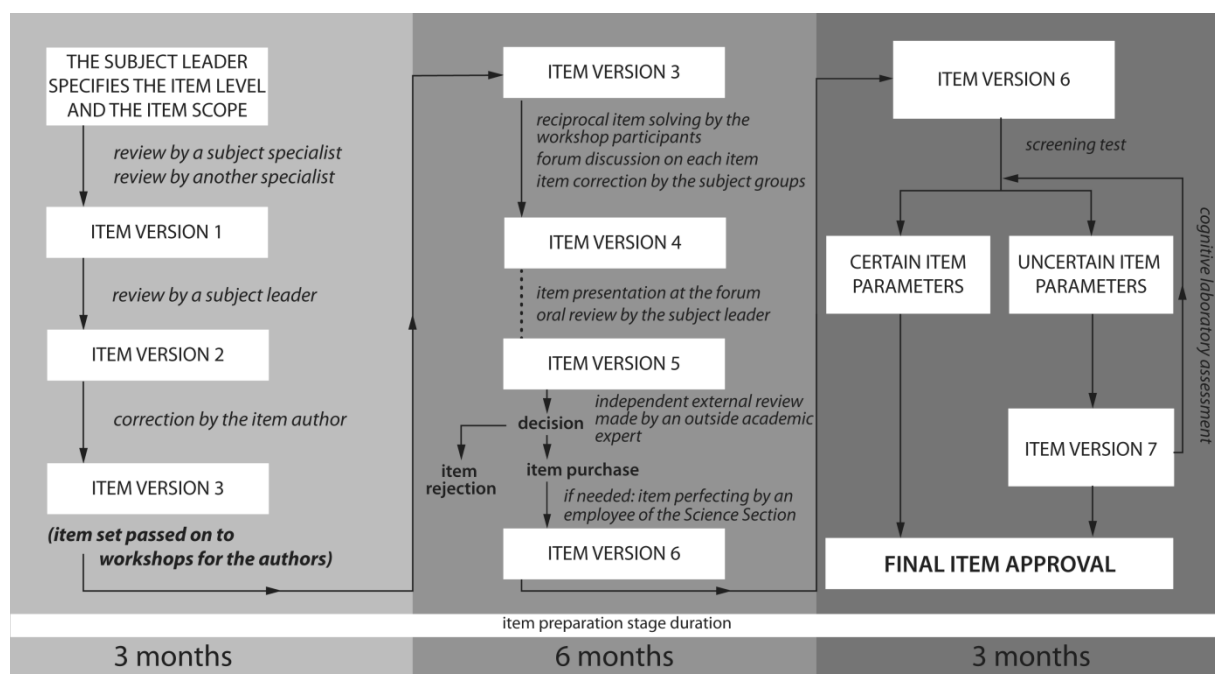


Figure 1. Stages of preparing cognitive items for the Laboratory of Thinking study (Chrzanowski and Ostrowska, 2018).

According to the academic recommendations of DeBoer *et al* (2008), these tools were pilot-tested in screening test in 2010 on a representative sample of 120 upper secondary schools (on ISCED2 graduates) to profit from feedback and enhance the validity of the inferences. The results were assessed with the use of the Classical Test Theory (CTT), and the Item Response Theory (IRT). More information about items used in *Laboratory of Thinking* may be found in the study of Chrzanowski and Ostrowska (2017).

In the present paper, the student results are analysed with regard to four exemplary items conceived as representative of four different vernacular misconception types. For each item, a chart was prepared in which students were divided in eight groups depending on their score obtained for the whole test.

Subsequently, the average score for every item was checked in each octile groups. The items were A Cloud over the Cup, Birch, Moss and Fungi, Gas Boiler, and The Beetle and the Potato. All the items in the study were various types of close-ended questions such as multiple-choice, true or false, two-tier, and matching questions. Then, a set of interviews was carried out to track the way how the students reach the answer.

The interviews using verbal probe technique (Willis, 1999) were performed on selected students to track the possible reasons for misconceptions. Twelve students were interviewed for each of the three assessed items. They were ISCED2 seniors (normally aged 15–16) right before the final external examination who had completed the whole curriculum for that stage and so were familiar with all the content covered by the items. They came from four schools from the Mazovian Voivodship (randomly chosen by the publication authors from the schools that took part in the *Laboratory of Thinking* study). The students were selected by their teachers to fit in one of the three categories: *gifted but not diligent*, *gifted and diligent*, and *not gifted but diligent*. In that sort of study, it is essential that the students should be communicative. Thus, the selection had to be made by their teachers who knew the students best. Consequently, there were boys and girls in each of the groups, but their numbers were not equal. It is worth mentioning that all the items selected for the whole *Laboratory of Thinking* study had preliminarily been assessed with the Differential Item Functioning (DIF) method to avoid gender-related differences in abilities in members of separate subgroups.

Each interview lasted at around 1.5 hour and was recorded. To begin with, the student solved a test of several close-ended questions in science subjects including the biology, chemistry, physics, and geography. To complete this task, the student had as much time as he or she needed and additionally could write down a commentary to each of the items. Then, he or she was asked for questions about the school subjects they preferred and the reason behind it. General and item-specific questions were asked for each of the items. The questions are found in Appendix 1.

FINDINGS

Based on our study, it was presented here the content and analysis of students' answers to the items that are representative of four different types of vernacular misconceptions. Possible reasons for those given misconceptions stem from the use of language itself and occur not only in Polish but also in other languages.

a) A word with two different meanings in scientific and every-day context

The presented item *A Cloud Over the Cup* was used during the field trial but was not part of the *Laboratory of Thinking* main study. It was implemented on a representative group of 208 students from 20 classes of lower secondary schools in Poland. The item was as follows.

Analyze the picture and complete the sentence choosing the correct answer. Justify your choice.



(1) Over the cup of hot coffee there is a 'cloud' of

- A. water vapour.
- B. droplets of water.

(2) Justify your answer.

- A. Water evaporates at 100 °C.
- B. Water vapour is a colourless and odourless gas.

Percentages of student responses are given in Table 3. The correct answer to both parts of the item was given only by 8.17% of students.

Table 3. The students' ($n = 208$) responses to the item *A Cloud over the Cup*

Answers	Students' choices
(1) A. water vapor.	83.7%
(1) B. droplets of water.	14.4%
No answer	1.9%
(2) A. Water evaporates at 100 °C.	40.4%
(2) B. Water vapor is a colorless and odorless gas.	50.5%
No answer	9.1%

* The correct answers shown in bold.

The main aim of the item was to verify if there is a vernacular misconception among students that the cloud can be seen over the cup containing a hot beverage is water vapour. Such a misconception might result from the fact that the students confuse the everyday-speech meaning of the word vapour or steam (tiny droplets of liquid water in the air) with its scientific denotation (water in gaseous state, without colour and smell).

About a half of the students gave the correct answer in the second part of the item, which may mean that they had memorized (learnt by rote) the fact that water vapour is a gas that can neither be seen nor smelt. However, at the same time the answers to the first part of the item show that this knowledge is "inert". For example, it has not been internalized. This means that students are able to remember and recall the

properties of water in liquid state, but do not actually understand what it mean in “real life”.

Another problem is that common experience may also be misleading. It is fully acceptable to call the cloud that comes out of a kettle or an iron “steam/vapour” in everyday life, whereas this term has a narrower and precise meaning in science. This is partly because whenever a gas is to be represented, it is usually depicted as a cloud in media, comic books, cartoons etc., even it cannot be seen in real. When the words “vapour”, “steam” or “gaseous” (regardless of the language we speak: French *vapeur*, Spanish *vapor*, Italian *vapore*, German *Dampf*, Russian пар “*par*”, Polish *para*, or the Japanese 蒸 “*jyou*”) typed into a browser, it provide us with images of clouds in the sky, fumes coming out from chimneys or white cloudlets bursting from kettles, cooking pots, steam-cooked dishes or even a water pipe. Likewise, such images is often come across in science/chemistry/physics textbooks.

Although the curriculum for teaching science and chemistry underlines the fact that students should be acquainted with the phenomena of water phase transition both theoretically and empirically, it turns out that what students think about water is full of contradictions and inconsistencies.

The analysis (Table 4) has shown that 35.1% of the students chose (1)A and (2)A, i.e. “water vapour” and “water evaporates at 100 °C”. The students adhere to safe (and not always relevant) definitions and clichés instead of trying to solve the specific problem. The most frequent (41.83%) combination was (1)A and (2)B, i.e. “water vapour” and “water vapour is a colourless and odourless gas”, which are conspicuously contradictory, as the students state that what they see above the cup is invisible water vapour. Only 4.81% of the students chose (1)B and (2)A, which probably stems from the fact that if they do not know what to choose and they opt for what seems more familiar (“water” and “100 °C” make the most people think immediately of boiling water).

Table 4. Students’ answers cross-tabulation

		2nd answer	
		A. Water evaporates at 100 °C	B. Water vapour is a colourless and odourless gas
1st answer	A. water vapour	A, A 35.1%	A, B 41.83 %
	B. droplets of water	B, A 4.81 %	B, B 8.17 %

* The correct answer marked in bold.

The interviews confirmed our assumption that the knowledge which the students have is incomplete, fragmented and often inconsistent. Some of the interviewees’ beliefs are listed in below.

- Water vapour does not have to (or even cannot) be colourless, and may be grey or white;
- Water vapour makes the students think not only of fog, dew or clouds (in the sky), but also of smoke, fire (of a building), bonfire or more generally of diffusion and cloud of condensed steam;
- Glass, nail polish or water can be colourless but still cannot be invisible. So, water vapour may be colourless and visible (as a white cloud) at the same time (which suggests some of the students do not understand the notion of colourlessness);

- Water vapour may sometimes be visible and sometimes invisible depending on the conditions;
- Droplets are “something bigger such as raindrops”, while “water vapour are tiny droplets in real”.

Exemplary verbal probing interviews data are gathered in Appendix 2 (transcribed verbatim).

b) A name suggesting that association is stronger than it really is

The following item, “The Beetle and the Potato”, was administered to 1934 middle school (ISCED2) graduates as a part of the first cycle of the study *Laboratory of Thinking*. Subsequently, the item was published on a website dedicated to educational purposes and therefore it could no longer be used in the next cycles of the study. The item is shown below as it was presented to the students. The frequencies of their responses are given in Table 5.

Originally, Colorado potato beetle lived only in North America in the Colorado state area. Interspecies relationships existing in that ecosystem kept the beetle population size at a constant level. Everything changed when humans brought a new plant to Colorado. This was the potato, native to South America from thousands of miles away. In the early 20th century, the beetle was brought to Europe with a shipment of American potatoes. Today, both the plant and the insect that feeds on it are found almost everywhere in the temperate climate zone of the Northern Hemisphere.

Using the information from the text, decide whether the following statements are true or false.

	Statement	True or false?
1	Even though people consider the Colorado beetle a pest today, originally it fulfilled an important role. It regulated the size of the potato population.	<input type="checkbox"/> True / <input type="checkbox"/> False
2	Potato is the only plant the Colorado beetle can feed on.	<input type="checkbox"/> True / <input type="checkbox"/> False
3	The Colorado beetle was able to spread over a large area because people started to plant potatoes.	<input type="checkbox"/> True / <input type="checkbox"/> False

The purpose of the item was to measure skills of students associated with analysing a short text and drawing conclusions from the presented information. No specific knowledge in biology was required. Quite surprisingly, many of the students seemed to ignore the key message carried by the text. For example, the fact that the most of its history the Colorado beetle had had no contact with the potato and the two organisms had only met relatively recently with human manipulation. Before that, given the absence of potatoes in the beetle’s natural environment, the insect, of course, was not able to feed on them (statement 2) or to regulate their population (statement 1).

Table 5. The student ($n = 1934$) responses to the item *The Beetle and The Potato*. All three statements were judged correctly by 24.1% of the students.

	True	False	No answer
Statement 1	38.8%	59.9%	1.3%
Statement 2	52.7%	45.9%	1.3%
Statement 3	80.9%	17.9%	1.3%

* The correct answers marked in bold.

The results presented in Table 5 show, however, that the majority of the students believed the potato was the only plant that Colorado potato beetle could feed on. It can be hypothesized as that this is mainly due to a very strong association between the beetle and the plant in the students’ minds. For decades in Polish schools, the Colorado

beetle was one of the textbook examples of a crop pest and the food chain consisting of a potato plant, a Colorado beetle and a pheasant has been one of the first ones that a primary school student would encounter.

This association also has its vernacular component as the Colorado beetle's name in Polish is *stonka ziemniaczana*, the latter word being an adjective meaning "potato-related". This is, of course, not an exception, as reference to the host plant also appears in this name of beetle in English and many other languages. In French potato is called *pomme de terre* (literally "ground apple"), hence the name of the insect *doryphore de la pomme de terre*. In the Spanish name is *escarabajo de la patata* or *dorifora*, and the Italian one is *dorifora della patata*, there can be found the word *patata* meaning "potato" in both languages. The beetle's names in German is *Kartoffelkäfer*, and in Arabic خنفساء بطاطس كولورادو '*khunfusa' btats kuluradu*' also include words for "potato" (*Kartoffel* and *btats*, respectively), while in Russian the term is колорадский картофельный жук '*koloradskiy kartofel'nyi zhuk*' and in Czech *mandelinka bramborová*, there can be found adjectives *kartofel'nyi* and *bramborová* both mean "associated with potato". There seem to be relatively few languages in which the insect is simply called "Colorado beetle" without any reference to potato, i.e. *coloradoskalbagge* in Swedish or *kolorado hamushi* (コロラドハムシ) in Japanese.

But how does the association that reflects in a fact (after all, Colorado beetles do feed on potatoes) become a misconception? It is believed that the problem arises when an automatic association replaces thinking in a student's mind. To solve the problem, the students were not expected to know the history of the Colorado beetle. They were only asked to analyse a short text about it. Those, who did so, had a good chance to choose the correct answer. Nonetheless, if a student believed that the association was so obvious that there was no need to pay too much attention to the text, the misconception could take over.

This hypothetical scheme is not limited to vernacular misconceptions. An oversimplified view of a phenomenon lies at the heart of many other types of misconceptions. The fact that, following a simple association is much easier than analysing the problem critically makes them even more appealing not only to students.

Figure 2 shows the percentage of students who correctly judged the statement 2 as false in eight groups identified as described in method section of the manuscript (1 – the students with the lowest score in the test, 8 – the students with the highest score). Even though a completely random choice would have resulted in a 50% success rate, the correct answer prevailed only in group 8. Moreover, the curve in Figure 2 has the shape that was observed in several other items which diagnosed some types of misconception. The students from groups 1 and 2 generally represent the lowest level of competencies and/or the lowest motivation to solve the item. Their answers tend to be random and one can see that in this case the percentage of correct answers is close to 50% indeed. In groups 3 and 4, which did better in the test, there is, paradoxically, a significant drop in the number of correct answers. This is where the misconception manifests itself most vividly. These students tried to solve the item, but they probably failed due to the misconception. As the level of skills and knowledge grew (groups 5–8), the number of correct answers rose, but only the best students (group 8) had a success rate larger than 50%.

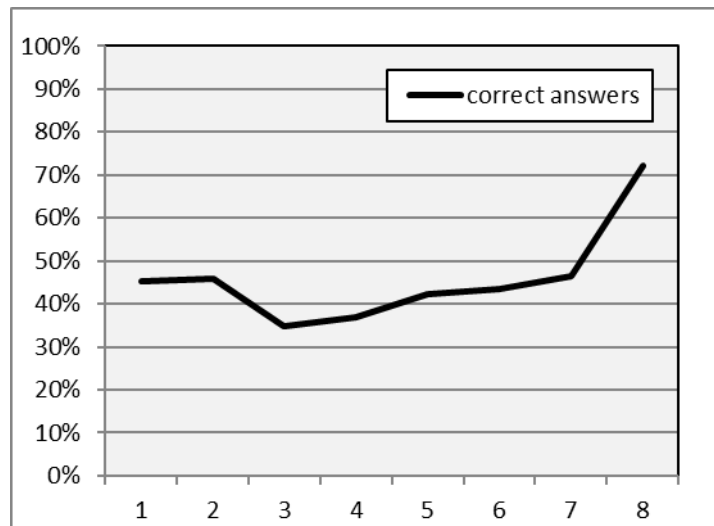
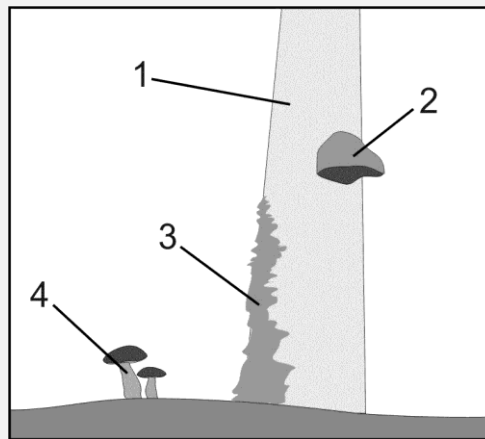


Figure 2. The distribution of frequency of the students' answers to the second row in the question in *The Beetle and The Potato* item

c) A term that only seems to be self-explanatory

The following item, *Birch, Moss and Fungi*, was presented to a sample of 251 ninth-graders (see Table 1) randomly chosen from 23 classes of lower secondary schools during the field trial but eventually was not used in the main study of the *Laboratory of Thinking*. The item is shown below as it was presented to the students during the field trial.

The picture shows four organisms living in a forest. Their names are listed in the table below.



For each organism, answer if it is an autotroph or a heterotroph.

Organism	Heterotroph or autotroph?
1. Birch	<input type="checkbox"/> Heterotroph / <input type="checkbox"/> Autotroph
2. Tinder fungus	<input type="checkbox"/> Heterotroph / <input type="checkbox"/> Autotroph
3. Moss	<input type="checkbox"/> Heterotroph / <input type="checkbox"/> Autotroph
4. Scaber stalk (a fungus)	<input type="checkbox"/> Heterotroph / <input type="checkbox"/> Autotroph

The frequencies of the student responses are shown in Table 6.

Table 6. The students' ($n = 251$) responses to the item Birch, Moss and Fungi. All the statements were judged correctly by 20.7% of the students.

	Heterotroph	Autotroph	No answer
1. Birch	19.5%	80.1%	0.4%
2. Tinder fungus	81.7%	17.5%	0.8%
3. Moss	57.8%	41.8%	0.4%
4. Scaber stalk (a fungus)	38.6%	60.1%	0.4%

* The correct answers shown in bold.

The results show that most of the students either did not properly understand the meaning of the terms autotroph and heterotroph or could not apply them to plants and fungi. Moreover, one should note a significant difference in the percentage of correct answers between the first two and the last two organisms listed in Table 6 (~80% and ~40%, respectively). It is argued that such results may be due to the specific vocabulary used in Polish to describe autotrophy and heterotrophy.

In most languages the terms for autotroph and heterotroph are variations of Greek words *αὐτότροφος* ‘*autotrophos*’ (from *autos* = “self” and *trophe* = “nutrition”) and *ἑτερότροφος* ‘*heterotrophos*’ (from *heteros* = “other” and *trophe*). To name a few examples: the French *autotrophe*, German *Autotroph*, Spanish *autótrofo*, Italian *autotrofe*, Czech *autotrofní organismus* or Russian *автотроф* ‘*avtotrof*’. In Polish the related words *autotrof* and *heterotrof* also exist, but the term *organizm samożywny* which means literally “self-feeding organism”, and *organizm cudzożywny* (“organism feeding on others”) is much more widely used especially in primary and lower secondary education. Among the examined languages in the study, a similar situation was found only in Japanese. An autotroph is called 独立栄養生物 ‘*dokuritsu eiyou seibutsu*’, literally “organism feeding independently” while a heterotroph is known as 従属栄養生物 ‘*juuzoku eiyou seibutsu*’ – “organism feeding dependently”. Therefore, both the Polish and the Japanese expressions have a similar meaning to the widely used terms derived from Greek. However there is an obvious difference in perception between words composed of stems and affixes coming from the mother language of the students and words derived from an unknown language (indeed, any Polish students are taught Greek in K12 nowadays).

To investigate the student understandings (or misunderstandings) for the terms of autotroph and heterotroph, the interviews were performed as described in the method section of the study. Most of the twelve interviewed students turned out not to know what autotroph and heterotroph meant, even though both terms are listed in the Polish national core curriculum. These interviewees also did not associate autotrophy with photosynthesis (at least not until guided by the interviewer). Therefore, many of the students tried to deduce the meaning of each term by analysing it. This led them to a false conclusion that an autotroph (in Polish “self-feeding organism”) is an organism that “gains its food by itself”, while a heterotroph (“organism feeding on others”) is an organism that “feeds on someone else’s expense” which makes it somewhat similar (or even equal) to a parasite.

The results from the interviews may explain why so many students classified the moss shown in the illustration as a heterotroph in the field trial. Probably the fact that, it was attached to another organism (birch) misled the students into thinking that it was a parasite like the tinder fungus. On the other hand, the saprophytic scaber stalk was incorrectly classified by most of the students as an autotroph, probably because it was depicted as growing from the soil, not from another organism.

In conclusion, an interesting vernacular misconception is associated with the Polish terms for autotroph and heterotroph. It is probably caused by the fact that these terms seem to be self-explanatory while their literal interpretation may be misleading indeed.

d) A term that usually appears in a misleading context

The item *Gas Boiler* shown in below was part of the first and the second cycle of the study *Laboratory of Thinking*.

There is a sticker on the gas boiler that reads:

In case you smell gas:

- ✓ Shut the gas valve
- ✓ Open the windows
- ✓ Avoid switching on electrical devices
- ✓ Extinguish all naked flame
- ✓ Call the gas emergency service and the gas installation service

Source: gas boiler manual

Which of the gases does the instruction on the sticker concern?

- A. Carbon dioxide.
- B. Carbon monoxide.
- C. Natural gas.
- D. Oxygen.

The responses of students to the item *Gas Boiler* are listed in Table 7. In the first cycle, the number of students was 1953 and in the second one it was 1874.

Table 7. The students' ($n_1 = 1953$; $n_2 = 1874$) responses to the item *Gas Boiler*

Answers	Students' choices	
	1st cycle	2nd cycle
A. Carbon dioxide.	13.3%	13.3 %
B. Carbon monoxide.	32 %	33.8 %
C. Natural gas.	52 %	50.5 %
D. Oxygen.	1.8 %	1.7 %
More than one answer	0.3 %	0.3 %
No answer	0.7 %	0.4 %

* The correct answers marked in bold.

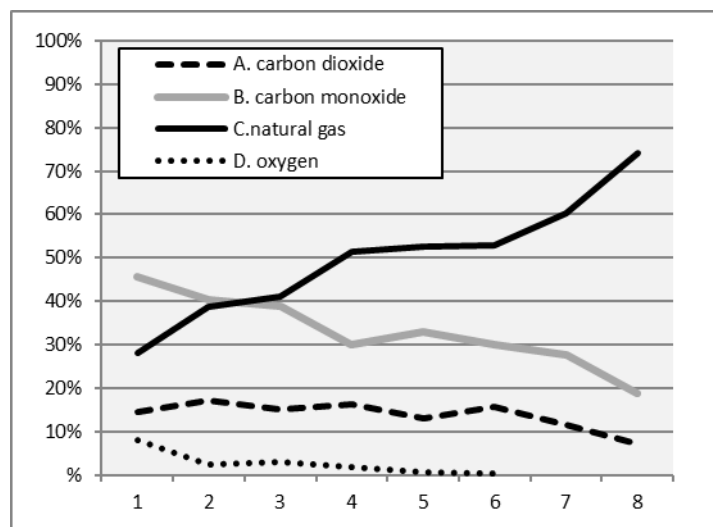


Figure 3. The distribution of frequency of the student answers to the question in the *Gas Boiler* item

The chart (Figure 3) shows the students' answers to the question. On the X axis the level of students is marked (1 being the group of the students who scored worst throughout the test, and 8 being the best scoring group), and the percentage of students from both groups who chose a given answer shown on the Y axis. The chart shows the results for the first cycle (in the second cycle, they were analogous).

The level of students' skills was higher when the percentage of correct answers was higher (i.e. "C. Natural gas."). The percentage of incorrect answers decreases along with the octile number. Yet, it should be noted that the answer B ("Carbon monoxide") clearly stands out. The percentage of B answers oscillates between 45.8% in students from the first octile and 18.8% in students from the last octile in the first cycle and 43.8% and 23.3% in the second cycle respectively.

It can be seen that students scored similarly in both cycles. The correct answers significantly outnumber the incorrect ones, beginning with the fourth octile (first cycle). Therefore, the task distinguishes average students from both good and poor students.

The first learning outcome in the Polish core curriculum for teaching chemistry at ISCED2 level is critical analysis of information: the student acquires and processes data from different sources through using information and communication technology. The context of the presented item is set in an everyday situation. The information provided in the stem comes from an actual sticker on a gas boiler. It is obvious that a grown-up citizen should be able to use data from the stem and draw conclusions from them. From a public health perspective, Omaye says that CO poisoning may be the cause of more than 50% of fatal poisonings in many industrial countries (Omaye, 2002).

Students should be familiar with the properties of all gases that appear in the item given the fact that they are listed in the curriculum and are recommended for experiments to be conducted in class (obtaining oxygen, hydrogen, carbon dioxide, examining their properties, detecting carbon dioxide in exhaled air).

A set of interviews was performed to learn more about the reason behind the student answers and the following conclusions were drawn based on them. When the students were asked why such information appears on gas boilers, it was obvious to them that it was for safety reasons. All but one of them managed to analyse the content of the instruction and knew the meaning of all of its subsections. It turned out that no more than a quarter of the students made a fully conscious choice. Some of the students knew the properties of the gases, but anyway they selected "carbon dioxide". Only a third of the interviewees knew that carbon monoxide was toxic and most of the students associated it with fires. Only one person knew the reason that natural gas had to be odorized and understood the term "odorization". The students' knowledge was fragmentary about O₂, CO₂, CO and CH₄ and their properties in standard conditions for temperature and pressure. Some of them were able to say (when guided) that carbon monoxide was toxic, while the others knew the properties of oxygen (e.g. that it is necessary for breathing). Only one person knew the formula for CO₂ and a quarter of the students knew what gas is used in cookers.

There are two main problems that ought to be stressed. First, students do not know the properties of methane (being combustible, odourless, colourless etc.). Second, most of the students associate carbon monoxide with smoke and fire. This may result from the image that is found in the media: people usually hear of carbon monoxide on the news when there is a fire emergency, therefore they mistake carbon monoxide for fire smoke (grey or black clouds, irritation of the eyes and throat, unpleasant smell of

burning matter). Data of exemplary verbal probing interviews are gathered in Appendix 3 (transcribed verbatim).

This may be perceived as a vernacular misconception since the common name of carbon dioxide in some languages may be misleading. For example, (*kolendamp*) in Dutch, (*kolshacha wayu*) in Hindi or (*fumée de carbone*) in French literally means “vapour of coal”, “gas of coal” and “smoke of coal”, respectively. In Spanish, it is sometimes referred to *gas carbonoso* (“coal gas”). Thus, all of them refer to the idea of burning fuel and other materials that produces clouds (visible and odorous). In Polish – the language our study was conducted in – it also seems deceptive, since the Polish word *czad* appears to be related to *kadzić* (“to incense”), albeit mistakenly, and makes many people immediately think of dense, acrid smoke. Some Poles also colloquially use the word *czadzić* to mean “to reek” or “to break wind” which explains why many people are sure *czad* (“carbon monoxide”) must have a smell.

DISCUSSION and CONCLUSION

There is not one language that could meet all the communication needs of individual or communities. Many languages, sublanguages, terminologies and registers coexist and intermingle as different domains of life come close to one another and overlap. Denotation is strictly connected with connotation and context, thus the awareness of their existence and relationships between them is a crucial factor in understanding the communication process and makes it possible to choose appropriate strategies. Teachers and students tend to speak different, separate languages, and often they are not conscious of that fact. This obviously leads to dissatisfaction of both teachers displeased with the learner results and the learners discontented with the teacher hermeticism. Although this dissatisfaction may seem frustrating, it also opens way to reaching a strategy that is means fruitful, plausible and intelligible (Posner, 1982), a strategy that works. Such a strategy is the way to undergo a conceptual change that helps to overcome the cognitive conflict and acquire a new language that opens new cognitive perspectives. There are three main types of conceptual change: firstly, *simple accretion*, that is adding new information (Chi, Slotte and Leeuw, 1994); secondly, *weak knowledge restructuring*, also referred as *assimilation* (Posner, Strike, Hewson and Gertzog, 1982) or *conceptual capture* (Hewson, 1981, 1982, 1985, 1992, 1996); and thirdly, *strong restructuring* (Carey, 1985, 1986, 1991), *radical restructuring* (Vosniadou, 1994), *accommodation* (Posner, Strike, Hewson and Gertzog, 1982) or *conceptual exchange* (Hewson, 1992) which means the old conception being replaced by the preceding one (or the previous one being sustained and the new one discarded).

The conceptual change may be related to *knowledge-as-theory* perspective (Ioannides and Vosniadou, 2002) or *knowledge-as-elements* perspective (diSessa, 1988), the former referring to simple *phenomenological primitives* (*p-prims*), and the latter using the notion of *misconceptions*. Phenomenological primitives can be considered as simple abstractions which generally need no verbal explanation (diSessa 1988), such as intuitively understandable principles: “the stronger the agency, the stronger the effect; the stronger the impediment, the weaker the effect”. Language *per se*, even in its simplest manifestations, is a more complex medium which inherently presupposes more indirectness (objects and ideas are not experienced as such, proximally, but distally, through the medium of phonology, lexis, syntax etc.), therefore terminology involved conceptual change requires a specific type of analysis that considers the phenomena on linguistic level. Such an approach requires a deeper differentiation of diverse kinds of misconceptions that arise when different

terminological systems meet: mainly when formalized scientific discourses is confronted with every-day, common speech.

The presented paper was aimed at naming different types and sources of vernacular misconceptions identified with the use of our long-term *Laboratory of Thinking* study. Four types of misconceptions were distinguished related to language found in students. These may be called:

- *amphibological misconceptions* (when a term has one meaning in science and another one in everyday life), as in *A Cloud Over the Cup*,
- *hypernymical-hyponymical misconceptions* (when a term suggests a stronger or narrower denotation than it has), as in *The Beetle and The Potato*,
- *pseudodeictic misconceptions* (when a term appears to be self-explanatory while it is not), as in *Birch, Moss and Fungi*, and
- *contextual misconceptions* (when a term usually appears in a context that gives a wrong impression about its actual meaning), as in *Gas Boiler*.

Each of the types was illustrated and discussed based on an example of an educational diagnostic tool through both quantitative and qualitative analysis. Sometimes it is difficult to make a clear distinction between the purely linguistic, terminology-related misconception and what is beyond words in it, that is the factual content and the extralinguistic context.

The relative scarceness of sources concerning specifically vernacular misconceptions may be because this issue is somehow neglected as a very narrow problem connected to the language of a given country or that may be easily corrected (Committee on Undergraduate Science Education, 1997), whereas it may actually be a universal and common hindrance that impedes student learning throughout the world. Unlike Bloom (1956), it is thought that this sort of problem is not a lower-level issue, because what seems easy and basic to some, may require higher cognitive level and more effort from others. Once again it should be stressed, according to Mason (2006), that memorizing simple words, as we often do, e.g. when learning a foreign language, is not the same as learning and understanding scientific terms and facts that underlie their definitions. Furthermore, as Gütl and García (2005) stressed that difficulty of conceptual learning must not be underestimated since not all scientific concepts are concrete and simpler to learn, also there are complex and abstract concepts, . What is more, it may be seen from the present study that many people do not really understand many fundamental concepts of science and as Nakhleh (1992) states that sometimes they may never be able to make up for it even as university graduates and postgraduate students.

Students tend to perceive the language used in class and the terminology connected with it as an abstract dialect (somehow similar to a dead language), that is only used for teaching and learning and has nothing or little to do with the so-called ‘real life’. Therefore, students may often not question the words of teacher, because they are used to hear things at school that are unclear, unfamiliar, and obscure. So, if they hear another unclear statement or term, they may not react to it. Consequently, it often happens that a teacher explains the subject matter to students who later give seemingly correct answers to his or her questions, but both parties are unaware of the fact that, in fact, they mean different things.

As described above, the terms *organizm samożywny* (“autotroph”) and *organizm cudzożywny* (“heterotroph”) were misinterpreted by students. It should be emphasized that the primary problem was that the students did not know what *organizm samożywny* (“autotroph”) and *organizm cudzożywny* (“heterotroph”) meant, and this was what made them try to figure out the meaning of these terms based on how they

sounded. Instead, the words *autotrof* and *heterotrof* had been used, probably the only difference would have been the lack of any guesses at all. Of course, such a change from a “wrong idea” to “no idea” is not our goal. It is believed that the term “producer” (Polish *producent* widely used in the literature) mean “an organism that produces its own food” describes an autotroph much more accurately than the expression “self-feeding organism”.

Another discussed problem – that of the Colorado potato beetle – is different as the association between the plant and the pest is generally correct and the students’ only mistake is to perceive it as an exclusive and obligatory one. It is not the only example in which the name itself is misleading. There are even worse, such as *horseshoe crab* (having nothing to do with horses, shoes or crabs) and *jellyfish* (being neither jelly nor a fish), or even more misleading because it is partially true such as *earthworm* (which does have something to do with soil but is not a worm).

The problem of misconceptions related to carbon monoxide has been examined by many authors (Derek, Velázquez-Angulo and Witherspoon, 2006; Penney, 2007; Pérez, Galada *et al.*, 2009). However, linguistic issues did not focus that may be the reason for these misconceptions. As it is stated afore, this misconception may be rooted in the language itself, and a reason for student mistakes may be the use of common (trivial) names.

There are numerous analyses concerning the problem of perceiving steam/water vapour concepts by students (Osborne and Freyberg, 1983; Stavy, 1990; Bar and Travis, 1991; Canpolat, Pinarbasi and Sözbilir, 2006; Håland, 2009 and González, 2010) and the problem seems to be related to concrete thinking of students that appear not to be able to internalize a phenomenon which is invisible. It is much easier to replace the hardly imaginable picture of invisible and odourless water vapour with visible clouds of condensed water droplets. When a phenomenon seems somehow exotic or mysterious to the students, it stands out and it is easier to notice and remember its properties, whereas the things that seem common and ordinary may pass unnoticed both by students and by teachers. Steam or vapour are everyday speech words that may seem deceptively familiar, whereas in the scientific context they may not be so.

Fighting misconceptions is difficult and often ineffective. It seems to be possible only if it is recognized and acknowledged about them (Sadler and Sonnert, 2016). As described by Tippet, a universal method is therefore to directly address the misconception in a so-called refutation text (Tippet, 2010). Dated 1984–2011, other more or less useful methods, have been summarized by Yang and Senocak (2013) is using conceptual conflict to confront and contradict student misconceptions and inducing students to reflect on their conceptions through computer simulations to facilitate conceptual change and correct misconceptions, inquiry-based approach, presenting conditions of the Conceptual Change Model (CCM), using schema training approach to train students on two scientific processes (domain-general). However, none of them is targeted specifically at fighting vernacular misconceptions.

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Appendix 1

List of general and item-specific questions asked to the students during interviews

General questions	Item-specific questions		
	Item	Question	
<ul style="list-style-type: none"> - Did you understand the question stem? - Did you understand the instruction? - Did you find the graphics clear? - Why did you choose such answers? 	A cloud over the cup	<ul style="list-style-type: none"> - What were you thinking when you chose the answer in task 1? Have a look at your answer in the second part of task 2. Do they match each other? - What do you think the reason for the laundry dries up? - What weather phenomenon does the cloud over the cup remind you of? - What is fog? How is it created? - What happens if you breathe out air on a freezing day? - At what temperature does water boil and evaporate? Does it always boil at 100 °C? Does pressure affect the boiling of water? 	
		Birch, Moss and Fungi	<ul style="list-style-type: none"> - Do you know what the difference between autotrophs and heterotrophs is? If the student answered “autotroph is an organism that feeds on its own”: - Am I [i.e. the interviewer] an autotroph? - Are the notions of autotroph and heterotroph related to whether the organism carries out photosynthesis or not?
		Gas Boiler	<ul style="list-style-type: none"> - Why is there an instruction sticker on the boiler? - What is the purpose of each information on the sticker? - What are the properties of carbon dioxide? - What are the properties of carbon monoxide? - Under what circumstances is carbon monoxide created? - What sort of gas is present in gas cookers? What does it smell like? - Do you know what gas odorization is? - What are the properties of oxygen?

Appendix 2

Exemplary student statements from the interviews when justifying their choice of answer in the item: *A Cloud Over the Cup*. The statements are transcribed verbatim.


- When there's hot water, there's a visible cloud, that is vapour.
- The cloud over the cup of coffee is hot air, which after meeting cold air becomes visible because the water condensates.
- If in the cup there is boiling water, the water evaporates. It changes from liquid to a visible gas.
- Because it looks like smoke.
- I've seen a cup many times and there was smoke above it.
- If there's something warm, droplets of water rise above it and form a cloud.
- Warm tea or coffee steams with a dim smoke.
- Why the smoke steams.
- I guess whenever tea boils there's smoke.
- The tea is hot, and that's why there is smoke.
- I think so because the cloud is in the sky, and vapour can appear over the cup.
- Vapour is, kind of, some white smoke.
- I've seen such smoke many times.
- Vapour is hot smoke that means the thing is hot.
- It is a colourless cloud.
- Hot water evaporates, which causes a white cloud to appear.
- Water after heating starts to evaporate, which appears as a white cloud.

Appendix 3

Exemplary student statements from the interviews when justifying their choice of answer in the item: *Gas Boiler*. The statements are transcribed verbatim.

- Carbon monoxide is when there's a fire.
- When there's a fire, we can smell that smoke.
- This carbon monoxide leaves dark stain.
- When there's a fire, people die because of this smoke (when it's about carbon monoxide).
- Carbon monoxide is grey and toxic. On TV they showed a fire and people were poisoned.
- Carbon monoxide makes you choke.
- Clouds of smoke.
- On the news they said that people got poisoned with carbon monoxide. They showed fire and smoke.

Assessing Conceptual Change Instruction Accompanied with Concept Maps and Analogies: A Case of Acid-Base Strengths

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ABSTRACT

The research assessed secondary school students' conceptions of acid-base strengths by using the conceptual change instruction accompanied with concept maps and analogies. These teaching strategies were employed to help them make unfamiliar events familiar. Within a quasi-experimental design, the sample of the study consisted of 73 secondary school students. Pre- and post-tests were used to collect data. The results showed that the experimental group that took the conceptual change-oriented instruction performed better than the control group. In light of the results, it can be concluded that employing such visuals and interactive materials as concept maps and analogies for achieving conceptual change is effective in generating better understanding of chemistry concepts.

Key words: Analogy, conceptual change, concept mapping, misconception, visualization

INTRODUCTION

Chemistry education systematically handles how to acquire fundamental knowledge about the universe. It concerns itself with the acquisition of knowledge on the properties, interactions and transformations of matter. It further seeks to act as a bridge between students' preconceptions of the world and scientific concepts (Barke, Hazari, & Yitbarek, 2009). Thus, students should be allowed to express their naïve worldviews in the class. By doing this, they are able to unveil their alternative conceptions of chemical changes. These prior conceptions help teachers to strategize and create relevant context that activate 'a need to know' (Ultay & Calik, 2016) situation before new scientific ideas are introduced. In the view of Taber (2001), such alternative conceptions are very common in many areas of science. Physics students generally hold alternative conceptions about force, work and energy, while biology misconceptions mostly concern the origin of the matter in plants and cell. Similarly, chemistry students think that the nucleus of an atom conveys



a certain amount of attractive force, which is shared between the electrons in the atoms. Since chemistry is a mainstay of science, technology and industry, it should be taught in a meaningful learning manner to minimize any alternative conception, from a more conceptual change-oriented point of view. Conceptual change deploys students' pre-existing conceptions as a necessary framework to solve problems, explain phenomena and functions in their world (Cetingul & Geban, 2005).

Any discrepancy between students' pre-existing conceptions and new concepts arouses conceptual conflicts, which need to be changed prior to further learning (Hanson, Kwarteng, & Antwi, 2015). A lot of researches have elicited students' misconceptions in such chemistry topics as particulate nature of matter (Chandrasegaran, Treagust, & Macerino, 2007), chemical equilibrium (Bilgin, 2006), acids and bases (Abanga, 2015; Ultay & Calik, 2016), mole concept, and chemical and physical changes (Hanson, Twumasi, Aryeetey, Sam, & Adukpo, 2016). For the acid-base topic, Pinarbasi (2007), who found out Turkish undergraduate students' conceptions of acids and bases, showed a number of implications for tertiary level teaching. Similarly, Yalcin (2011) depicted that science student teachers at different grades had misconceptions of acid-base concepts. Also, he did not find any significant difference between the grades from the first-year to the fourth-year one. This means that students at all grades and student teachers have similar misconceptions of acid-base chemistry. However, identifying students' misconceptions is not enough to overcome them or attain conceptual change (Hanson, 2018). For example; Say and Ozmen (2018) used concept cartoons to decrease Turkish students' alternative conceptions of the structure and properties of matter. However, few studies have been concentrated on the use of conceptual change to enhance conceptual understanding at a specific grade in the African continent.

Acid-base concepts are fundamental for chemistry to explain most chemical interactions in the environment and human body. Cros and Maurin (1986), who examined the first-year students' misconceptions of acid-base topic, found that most of them thought that acids were more dangerous than bases. Banerjee (1991), who developed a test to diagnose students' misconceptions of acid-base equilibrium, found that the students viewed that rain water was neutral. Similarly, they implied that pH of the ethanoic acid would be less than or equal to the pH of hydrochloric acid solution in water. Boz (2010), who obtained Turkish chemistry student teachers' alternative conceptions of acids and bases, found that most of them did not have challenges with macroscopic properties, neutralization, and distinction between 'strength' and 'concentration' of acids and bases. Hanson's (2011) findings on acid-base concepts showed that elementary school students saw all acids as strong and powerful burning substances. They also added that all acids, except for those in fruits, were poisonous. Bradley and Mosimege (1998), who studied student teachers' conceptions of acid-base topic, revealed that they did not consider indicators as a necessary for the presence of basicity or acidity even though they could be used to test acid strength. Bradley and Mosimege (1998) also found that their students intimated that aqueous solutions of all salts as neutral. These studies have suggested that students bring their pre-conceptions to class. This needs to employ conceptual change approaches remedying alternative conceptions. For example; Ozmen, Demircioglu and Coll (2009), who exploited laboratory activities accompanied with concept mapping (which is a conceptual change approach), reported a better understanding of the acid-base chemistry.

Conceptual change is viewed as a process of replacing misconceptions with scientific ones. Using conceptual change strategies helps students to re-construct their ideas and/or pre-conceptions. Analogy is another effective strategy in overcoming misconceptions. It helps students

to learn new information as they discard or modify misconceptions in scientific ways. New materials then become more intelligible to students as compared with familiar materials. For instance; Cetingul and Geban (2011), who combined a ribbon analogy with concept maps and conceptual change approach to explain valences in the acid-base topic to the Turkish students, depicted that this social framework helped them to create a model of the molecular world (Cetingul & Geban, 2011). Analogies can be seen as anchors to conceptual bedrocks. There is an explicit effort to make unfamiliar familiar. In using analogies, students construct their own knowledge and apply them to new situations. Stavy (1991) stated that using analogy to overcome misconceptions about *conservation of matter* was an effective tool in teaching chemistry.

The use of concept maps as a teaching strategy is also very helpful to promote conceptual understanding as found by Aydin, Aydemir, Boz, Dindar and Bektas (2009) and Ozmen, Demircioglu and Coll (2009). A concept map, which is a useful graphical representation, can be used for any information on nodes and propositions. A central concept firstly is identified, and then linked with each other concepts. Later, concise and familiar concept labels are used. In case of concepts of different generality, more general concepts are centrally located. More specific concepts are peripherally placed on the concept map. Concept maps are flexible tools that help to represent one's knowledge. It allows students to visualize knowledge in graphical form and to makes retention and recalling easier. Besides, it positively impacts on their affective and psychomotor domains. They are also used as diagnostic tools to elicit students' knowledge structures and frameworks. Investigating students individually to elicit their problems may be intimidating and time consuming. To deploy a more time-efficient and less stressful approach, students are asked to prepare their own concept maps. Hence, they are able to reveal their alternative conceptions, integrated ideas and the extent of interlinks at key ideas. Concept maps are in a harmony with tenets of constructivism. For example; Taber (1994), who employed concept mapping, found positive conceptual gains and stimulated their interests and motivated engagements.

Constructivist science teaching focuses on what is discovered in the process of learning and requires actively first-hand experiences. Students' pre-existing knowledge may hamper their efforts to achieve conceptual understanding towards the accepted scientific view even though they are very active in constructing knowledge. Overall, identifying students' prior conceptions before teaching could act as a bridge linking what they have known in a more affable way with the targeted one. For such educational purposes, diagnostic tests are used to elucidate students' own ideas of science concepts (Bayrak, 2013). Hence, diagnostic tests help science/chemistry educators to gain insights into students' conceptions.

Purpose

This study purposed to examine grade 11 students' prior conceptions of acid-base topic and the effect of conceptual change instruction accompanied with analogies and concept maps on their conceptual understanding of the acid-base concepts.

Research Questions

1. What prior conceptions do students have about acids and bases?
2. Is there any significant difference between the conceptual change instruction and traditional instruction in remedying the students' misconceptions of the acid-base topic?
3. What do the students in the experimental group think about their engagement with concept maps and socio-scientific analogies?

METHODOLOGY

Within a pre-test, post-test, control group design, the sample of the study comprised of 73 Grade 11 students drawn from two different schools. Two different teaching methods, which lasted three weeks, were randomly assigned to the schools. The experimental group (N: 36) received conceptual change lessons oriented with concept maps and real life-based analogies. The control group (N: 37) was exposed to teacher-centered instruction called traditional or didactic teaching. Ultay and Calik (2016) had carried out a similar study with three groups of pre-service science teachers using different teaching designs (REACT strategy, 5Es model and traditional instruction). They employed Acid-Base Chemistry Concept Test (ABCCT). Given a blend between a Turkish model by Calik and Ayas (2005) and a Thai model by Artdej, Ratanaroutai, Coll and Thongpanchang (2010), an acid-base diagnostic test (ABDT) was adapted and administered after ensuring validity and reliability. The diagnostic test was designed to unveil and measure students' naïve conceptions and conceptual understanding of acids and bases. Thus, its open-ended construction gave them an opportunity to express their own innate conceptions. To sum up, a 15-item multiple choice diagnostic test was developed from the gathered misconceptions.

The test was firstly pilot-tested with a different school, which had similar characteristics with those in the real study. In view of Meriwether (2001), the pilot study enhances the reliability of instrument. The 15-item diagnostic test was based on misconceptions depicted by Taber (2001) and Bradley and Mosimege (1998). The content validity of the instrument was confirmed by three senior chemistry colleagues. Cronbach's alpha coefficient (Cronbach, 1951) was used to calculate the reliability of the instrument (diagnostic test in this case). Its Cronbach alpha reliability was found to be 0.76, which indicates an acceptable reliability of an instrument suggested by Bryman (2008). Some common misconceptions reported in the related literature were also employed to construct the ABDT.

Procedure

The study purposed to compare the effectiveness of conceptual change-oriented instruction on Grade 11 students' understanding of the acid-base concept with traditional one. The study was conducted in two public high schools in Cape Coast, Ghana. The ABDT was administered as a pre-test before the teaching intervention. Then, the same test was re-administered as a post-test after the teaching treatment. Hence, the study intended to determine any significant difference between them. The control group was instructed with traditional methods (i.e., lecture, discussion and solving algorithmic problems) suggested by the Ministry of Education. A summary of the day's lesson was written as core points. Hence, students copied them. Their attention was carefully drawn to important facts, equations, and symbols. The experimental group was taught via the interactive and student-centered approach. They were exposed to clearly some common misconceptions of acids and bases. Hence, they analyzed them through probes and discussions, which resulted in re-structuring their conceptual understanding. In this study, the students were specifically asked about the strengths of acids. A 15-item diagnostic test was handed out to all students again at the end of the treatment period. Each item was scored with a point.

RESULTS and DISCUSSION

Percentages of grade 11 students' misconceptions in the pre- and post-test are shown in Table 1.

Table 1: Percentages of *misconceptions* in the pre- and post-test for the experimental and control groups

Misconceptions	The experimental group (N: 36)				The control group (N: 37)			
	Pre-Test		Post-Test		Pre-Test		Post-Test	
	f	%	f	%	f	%	f	%
1	12	33.3	4	11.1	14	37.8	7	18.9
2	9	25.0	1	2.8	7	18.9	2	5.4
3	10	27.8	0	0.0	11	29.7	4	10.8
4	8	22.2	0	0.0	7	18.9	2	5.4
5	4	11.1	2	5.6	6	16.2	3	8.1
6	21	58.3	1	2.8	19	51.4	1	2.7
7	18	50.0	8	22.2	19	51.4	11	29.7
8	14	38.9	3	8.3	17	46.0	8	21.6
9	13	36.1	1	2.8	11	29.7	7	18.9
10	14	38.9	0	0.0	15	40.5	9	24.3
11	17	47.2	3	8.3	13	35.1	7	18.9
12	26	72.2	1	2.8	27	73.0	15	40.5

f = frequency

The results of independent samples t-test showed no significant difference between the groups' pre-test mean scores of the ABDT. This means that their pre-conceptions were almost equivalent at the beginning of the study ($t=2.07$, $p>0.05$). They could identify very simple properties about acids and bases such as acids being sour and bases being bitter. Further, the experimental and control groups had similar misconceptions of acids and bases at especially sub-microscopic and symbolic levels. Indeed, the same thing was valid for macroscopic properties (Boz, 2010; Pinarbasi, 2007). For example; the students thought that the pH value of ethanoic acid (CH_3COOH) was higher than that of ammonia (NH_3) solution. The students further iterated that pH values of acids were greater than those of bases. They also intimated that ammonia was a stronger base than sodium hydroxide (NaOH) because it had more hydrogen atoms. That was a misinterpretation in identifying the bases.

The results of independent samples t-test revealed a significant difference between the experimental and control groups' post-test mean scores of the ABDT in favour of the experimental ones ($t=2.07$; $p<0.05$). The experimental group scored higher marks than did the control one. The retention percentage of the misconceptions in the experimental group was 1.85 in the post-test (which had been improved from 13.83% in the pre-test), while that of the control group was 5.55 in the post-test (which had been evolved from 13.83% in the pre-test). Some of the scientific conceptions identified by earlier Turkish and Thai studies are as follows:

1. Strong acids completely ionize while weak acids partially ionize in aqueous solutions
2. Concentrated acids contain higher moles of acidity to volume of solution
3. Strong acids can form dilute solutions if their amounts are small as compared with the volume of water
4. HNO_3 is a stronger acid than HCOOH because all molecules of HNO_3 completely ionize

Furthermore, new ideas elicited by the current study are in the following:

1. NaOH is a stronger base than NH_3
2. NaOH has a higher pH than NH_3
3. NaOH and KOH are strong bases because they have higher concentrations of OH^- ions
4. Strong bases completely ionize to produce many OH^- ions while weak bases partially ionize at molecular level.
5. NaOH has a higher pH while NH_3 has a lower pH

Students construct new knowledge with prior knowledge (Cetingul & Geban, 2011). It is always important to consider and collate their prior knowledge on all topics before teaching them. Identified alternative conceptions should be discussed through a teacher's guidance to unveil familiar relationships so that students can socially form their own scientific ideas. Pointing out their misconceptions without any intervention and/or treatment does not help to achieve conceptual change. Meaningful learning requires to actively engage students in problem-solving situations, critically think and re-organize old ideas with new ones. Thereby, based on their prior knowledge, they test their ideas and approaches to construct new knowledge. Also, they apply newly generated knowledge to novel situations by meaningfully linking their new knowledge to the existing conceptual frameworks (Aydin, Aydemir, Boz, Centin-Dindar, & Bektas, 2009).

This current study planned lessons and materials about the acid and base concepts with flexibility given grade 11 students' naïve ideas. The three-week treatment helped them to acquire a deeper understanding and better visualize the concepts. Because basic visualization depends on the operations of metaphors and analogies, analogical reasoning in the current study afforded them to review/revise their prior knowledge, realize their common misconceptions and then correct them. Since the use of analogies served as a bridge between everyday life phenomena and classroom science, it engendered a better conceptual understanding. For example; they were able to make comparisons amongst HCl, H_2SO_4 and H_3PO_4 , by analyzing the relationship(s) between the number of hydrogen atoms (in reality H^+ ions) in an acid and its acid strength. Majority of them answered that H_2SO_4 , which had more hydrogen atoms, would have a higher acid strength. They intimated that H_2SO_4 , which contained one more hydrogen atom, would have twice the strength of the HCl acid, and H_3PO_4 would have three times that of HCl, which had only one hydrogen atom. This is not true in reality, as regarded by scientific findings.

Analogies had to be provided for students to appreciate that sometimes one bulb, as in the compact fluorescent lights, sometimes one bulb for students. That is, the compact fluorescent lights could give more light in that they are more powerful than two or three tungsten 'onion' bulbs of the same capacity. If we link this analogy again to the acid strength and number of hydrogen atoms, HCl is a stronger acid than H_2SO_4 because it gives off more hydrogen ions to the water than the latter one. Such answers were probed through guided questions until a correct answer was arrived at. Then, to establish real-life analogical reasoning experiences, they were asked to respond the question 'How do you determine the strengths of bulbs at home, without reading the inscribed wattage.' They indicated that the brightness of the light could be used. 'If a bulb gave off a lot of light, it was stronger than one with little light'. These findings were similar to what Boz (2010) found among Turkish chemistry student teachers. Namely, like the Turkish students, these Ghanaian students did not have much difficulty with macroscopic properties of the acids and bases but they possessed pitfalls in comprehending the distinction between 'strength' and 'concentration' of the acids and bases.

Unlike previous studies, the students under investigation were able to use the degree of ionization and the presence of the hydroxyl ion (OH^-) for classifying the strengths of the acids-bases. That is, a base will be strong and light up a bulb with intensity or be weak and light up a bulb with less intensity. Thus, the students were able to build concept maps about the strengths of bases after analogical discussions for the acids. They distinguished the strengths of the bases in the solutions of ammonia and sodium hydroxide with scientific reasons. Further, they used examples from everyday life to support their claims.

Students were also encouraged to use concept maps to express any 'acid-base' idea. The use of concept maps generated a lot of excitement (Taber, 1994; Ozmen, Demircioglu, & Coll, 2009). Each group tried to relate some of their linkages/propositions to real life situations. They were promoted to select their own analogies from their close environments. For example; the students chose such examples as lemon on their concept maps of the acids. Other students also used plantain ash (KOH/NaOH) to produce a salt. This helped them to form realistic relationships between their used terminologies and scientific ones. Hence, they discussed the acid-base concept to enable them to do away with any confused difficult concept. Since the acid-base topic includes inter-related concepts, they should be taught through appropriate constructive approaches to avoid misconceptions hindering further chemistry learning (Bayrak, 2013; Boz, 2010).

The teacher in the current study acted as a facilitator to promote the students to freely interact with each other and form their own concepts using pre-existing knowledge. The 'dim and bright bulbs' analogy seems to have often been more useful than didactic instruction with a thousand words.

CONCLUSIONS and IMPLICATIONS

The traditional instruction was ineffective in eliminating the students' misconceptions of the acid-base topic (Andre & Chamber, 1997; Mikilla, 2001; Hanson, 2011; Abanga, 2015). In fact, it is believed that the traditional method only attempts to transmit teacher's knowledge to his/her students in a uni-dialogical stream, and does not relate school knowledge to everyday life. Teachers act as the persons 'knowing all.' But, conceptual change approaches take student-centered learning into account and enable them to cultivate their own ideas facilitating to reconstruct the scientific knowledge/ideas as was also found by Ultay and Calik (2016). If students are not systematically forced to consider their worldviews, they will integrate new content into them. However, addressing their misconceptions and acknowledging their pitfalls in their thinking make their minds more affably to new content/knowledge. Therefore, teachers should become aware of alternative teaching strategies allowing to collate and remedy their students' prior knowledge. This suggested approach, which is flexible to use, makes lessons more interactive.

The findings revealed that concept mapping accompanied with analogies was more enjoyable in assisting students to get interlinks of the related concepts, and reduced their alternative conceptions. Further, such a treatment seems to have resulted in more social collaborations. The current study also showed that context-based chemistry concepts afforded the students to retain newly generated knowledge in their long-term memories, just as Ultay and Calik (2016) found in their use of the REACT strategy. This finding is consistent with those by Aydin, Aydemir and Boz (2009) and Stavy (1991). That is, an increase in familiarity with learning objects and environments promotes constructivist learning.

In light of the results, curriculum developers and textbook authors should focus on a few common misconceptions and handle them within proper conceptual ways. Information and

communication technology tools and software could be designed to improve students' representational levels of the 'acid-base' topic. Since these prior knowledge and/or naïve ideas are strong predictors of students' achievement in further chemistry studies, teachers should take students' prior knowledge of acids and bases into account by developing their own lesson plans. Furthermore, because most life reactions contain the acidity or basicity media to facilitate reactions, suitable strategies must be developed by teachers to get students to gain mastery over these concepts.

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Appendix A: An example of a concept map with some given words

Weak acid, strong acid, acid strength, weak base, base strength, proton, hydroxide ion, hydrogen ion, acid, base, salt, and named acids and bases

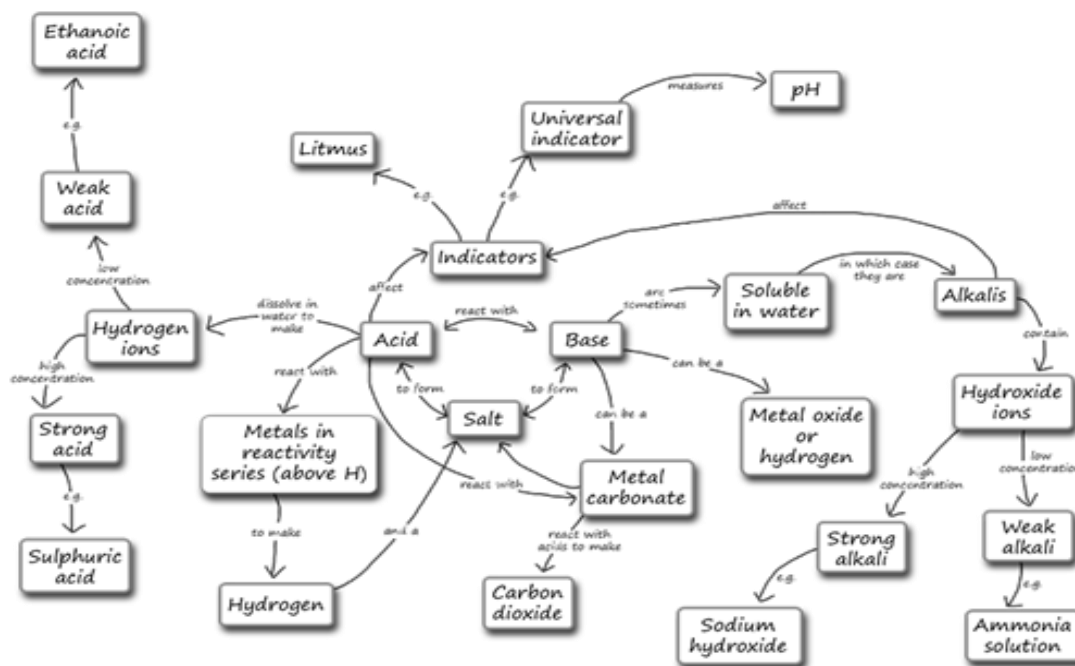


Photo: <https://www.google.com.gh/conceptm>

Exploring the Relationship between Preservice Science Teachers' Beliefs and Self-Regulated Strategies of Studying Physics: A Structural Equation Model

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ABSTRACT

This study aimed at exploring a structural equation model on the relationship between preservice science teachers' beliefs and self-regulation strategies of studying physics. The sample of the study consisted of 248 pre-service science teachers drawn from department of physics education at one state university and one state Islamic university in Jambi, Indonesia. The Colorado learning attitudes about Science Survey (CLASS) was used to measure their beliefs of physics and physics learning. Furthermore, motivated strategies for learning questionnaire (MSLQ) was also deployed to measure their self-regulation strategies on studying physics. Variance-based structural equation modeling (SEM with PLS) showed that sophisticated beliefs were positively correlated to the use of elaboration, organization, and metacognitive strategies whilst naïve beliefs were positively correlated with the use of rehearsal and elaboration methods. This study provides insightful implications for educators, especially lecturers, on how to plan, design, and practice the appropriate and effective pedagogical strategies to replace naïve beliefs with sophisticated ones, and to enhance the use of self-regulated strategies in studying physics.

Keywords: Self-regulated strategy, structural equation modeling, student beliefs.

INTRODUCTION

Physics, which is a branch of science, has its own uniqueness incorporating abstract concepts and requires an idealization through a mathematical modeling. This makes physics difficult to be conceptually understood and taught (Duit, Niedderer, & Schecker, 2007). Higher percentage of researches in physics education compared to other science branches such as chemistry and biology support these facts. As a matter of fact, Duit et al. (2007) indicated that 64% of the documented studies were in the physics education, whilst the percentages of those in the biology education, and chemistry education were 21 and 15 respectively. Various educational studies indicated that student success in studying physics



depends not only on the cognitive aspects, but also on the social and individual traits of students. That is, students' beliefs of characteristics of physics knowledge and knowing how to obtain it influence their successes in studying physics (Hammer, 1994; Kortemeyer, 2007; Otero, 2004). Furthermore, Kortemeyer (2007) states that students with sophisticated beliefs understand how the characteristics and processes of knowledge in physics are constructed. Also, they are able to monitor, evaluate, and improve their learning processes. On the contrary, students with naïve beliefs view physics as memorizable information or facts, and pay more attention to remember the formula and problem-solving algorithms instead of developing conceptual understanding of physics.

Students' beliefs and interrelated various aspects of student learning have mostly been explored in such European countries as Germany (Bromme, Pieschl, & Stahl, 2010), Italy (Mason, 2000; Mason & Boldrin, 2008), Norway (Bråten & Strømsø, 2005), and Spanish (Limon, 2006). For the Asian context, those have dominantly been investigated such countries as Taiwan (Lin, Deng, Chai, & Tsai, 2013, Tsai, 2000), Hongkong (Chai, Ho, & Ku, 2011), Singapore (Chai, Teo, & Lee, 2010), Korea (Hyo-Jeong, Ji-Yeon, Seak-Zoon, & Sang-Kon, 2010), and Turkey (Kapucu & Bahçivan, 2015; Yilmaz-Tüzün & Topcu, 2010). However, even though Indonesian physics studies have focused on students' beliefs and their relevance to various learning activities, how students use their self-regulated strategies in studying physics have still been unexplored. Cascallar, Boekaerts, and Costigan (2006) state that self-regulated ability plays a key role in determining student's active engagement in the learning process. Self-regulated learning, which is a complex feature, involves multidimensional constructs (i.e., cognitive, affective, motivational and behavioral aspects). Also, Hofer and Bendixen (2012) emphasize a need for portraying students' beliefs and related learning aspects (e.g., the role of self-regulated strategy in physics learning). Hence, the current study intends to broaden the researches on students' beliefs to a developing country (i.e., Indonesia).

Purpose

This study aimed at exploring a structural equation model on the relationship between preservice science teachers' beliefs and self-regulation strategies of studying physics. The following research question guided the current study: What does the structural equation model indicate on the relationship(s) between pre-service science teachers' beliefs and self-regulated strategies in studying physics?

Hypothesis

As seen in Figure 1, the current study hypothesized that students' beliefs would contribute to their self-regulated strategies in learning physics (rehearsal, organization, elaboration, critical thinking, and metacognitive).

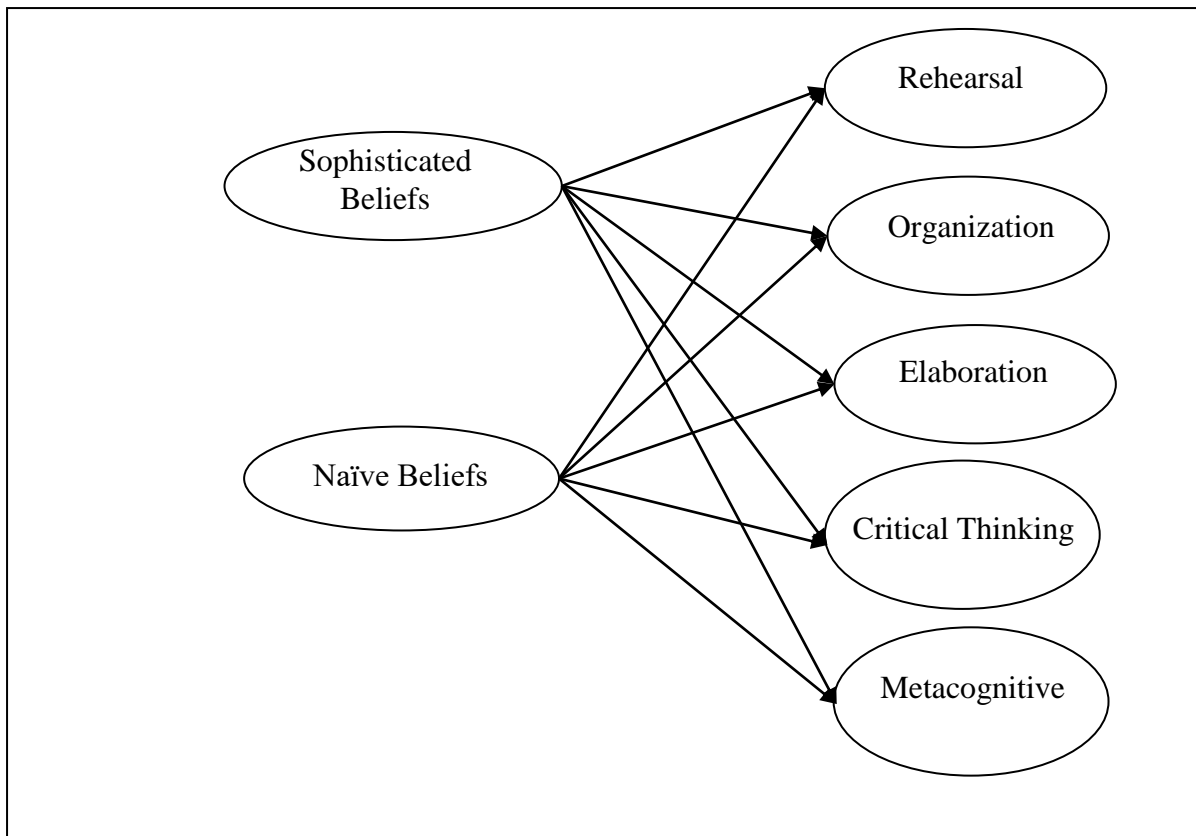


Figure 1. *Research Model on Students' Beliefs and Self-regulated Strategies in Studying Physics*

LITERATURE REVIEW

a) Student Beliefs on Physics and Physics Learning

Psychology researchers define students' beliefs of learning as the nature of knowledge and/or knowing. Two theoretical frameworks scrutinize students' beliefs: developmental and multidimensional (Hofer & Pintrich, 1997). Developmental framework sees beliefs as a pattern sequence of cognitive development. Five major models under the framework are available: "Perry scheme" (Perry, 1970), "women's ways of knowing" (Belenky, Clinchy, Goldberger, & Tarule, 1986), epistemological reflection (Baxter Magolda, 2004), reflective judgement (King & Kitchener, 1994), and argumentative reasoning (Kuhn, 1991). Although each model has a different label for each developmental stage, they possess several common characteristics. Specifically, absolutism, multiplism, and evaluatism are considered as important features in describing students' beliefs (Muis, 2007). Schommer (1990) proposes different perspectives in describing students' beliefs: structure, certainty, source of knowledge, and control and speed knowledge acquisition (Hofer & Pintrich, 1997). Multidimensional framework which has initiated an important research line, links epistemological beliefs to various aspects of student's learning, for example, student performance and classroom learning environment. In line with Schommer (1990), Hammer and Elby (2002) also offer another model for multidimensional framework (called epistemological resources) and view epistemological beliefs as a more context dependent (i.e., a particular physics course) (Hammer, 1994b).

In the last few decades, several researches of students' beliefs have practically tested the characteristics of knowledge. Most of them has analyzed the interrelationships between

beliefs and various aspects of student learning, such as conceptual understanding (Cano, 2005; Chu, Treagust, & Chandrasegaran, 2008; Rebello, Siegel, Witzig, Freyermuth, & McClure, 2012; Sahin, 2010), and the use of self-regulated strategies and metacognitive (Bråten & Strømsø, 2005; Yilmaz-Tüzün & Topcu, 2010), attitude (Kapucu & Bahçivan, 2015) and academic achievement (Lin et al., 2013). Nevertheless, how students' beliefs interact with their self-regulated strategies in studying physics has never been explored yet for the Indonesian context. In view of Hofer and Bendixen (2012), further studies on students' beliefs within and across cultures are needed to illuminate the constructs of personal epistemologies.

Some questionnaires are specially developed to measure students' beliefs about physics and physics learning. These are: the Maryland Physics Expectation Survey (MPEX), Views about Science Survey (VASS) (Halloun and Hestenes, 1998), Epistemological Beliefs Assessment for Physics Science (EBAPS) (Elby, Frederiksen, Schwarz, and White, 2001), and The Colorado Learning Attitudes About Science Survey (CLASS) (Adams et al., 2006). The CLASS, which is the last one, was developed by taking earlier instruments (MPEX, VASS, and EBAPS) into account. A 27-item CLASS questionnaire includes Likert scale statements within 8 sub-dimensions: a real world connection, personal interest, sense of effort, conceptual connections, applied conceptual understanding, problem solving (general), problem solving (confidence), and problem solving (sophistication). There are some principal differences between the CLASS and other instruments (Adams et al., 2006). For example, the CLASS instrument addresses various important issues of physics learning and concisely constructs all phrases in each item. By avoiding double interpretations for students or experts, the CLASS categorizes each item into the category or scale for rigorous statistical analysis. Overall, each category or scale characterizes important aspects of the student's mindset. Despite its advantages vis-a-vis other instruments, several researchers have criticized some overlap items.

Douglas, Yale, Bennett, Haugan, and Bryan (2014) reported that the CLASS questionnaire with eight belief dimensions (a total of 26 items) are highly complex. In addition, they implied that several items were categorized under more than one dimension. For example; the item "If I get stuck on a physics problem, there is no chance I'll figure it out on my own" fell into the dimensions of the applied conceptual understanding, problem solving in general, problem solving confidence, and problem solving satisfaction. This indicated that the construct of the CLASS questionnaire was not unidimensional. exploratory and confirmatory factor analysis by Douglas et al. (2014) pointed to three belief dimensions; personal application and real world relation, problem solving/ learning, and effort/ sense making. The current study ensured the validity and reliability of the questionnaire measuring Indonesian university students' beliefs through exploratory and confirmatory factor analysis .

b) Self-Regulated Learning

Understanding students' capacities or abilities of students to direct their formal and informal learning has become a central and debatable topic for educators, policymakers, and educational researchers. Given various models of self-regulated learning, Puustinen and Pulkkinen (2001) referred to two types of self-regulated learning, namely goal-oriented and metacognitive-oriented self-regulated learning. A goal-oriented definition views self-regulated learning as a result-oriented process emphasizing the constructive or self-generated character of self-regulation (Muis, 2007). This definition asserts that monitoring, regulating, and controlling in the learning process involves not only cognitive, but also motivational, emotional, and social factors (Pintrich & De Groot, 1990; Zimmerman, 2000; Zimmerman & Schunk, 2001). Metacognitive-oriented one emphasizes metacognitive abilities as a

significant part of self-regulation. Although these two models have the different foci on the components of self-regulated learning, all authors have the same assumption regarding SRL. Indeed, all models assume that students actively construct knowledge, set goals, and strategies from internal and external contexts by controlling cognitive, motivational, and behavioral aspects of the learning environment during the learning process (Muis, 2007).

The goal-oriented SRL is rooted by social cognitive theory by Bandura (1997). That is, self-regulated learning is a result of the interaction between personal, behavioral, and environmental factors. Also, social cognitive perspective views the quality of self-regulated learning as the dependent of metacognitive ability (Zimmerman, 2000). For example, Learning process includes to choose cognitive strategies and emphasize personal aspects, namely beliefs and motivation. Furthermore, Zimmerman (2000) draws self-regulation as a triadic cycle process (see Figure 2).

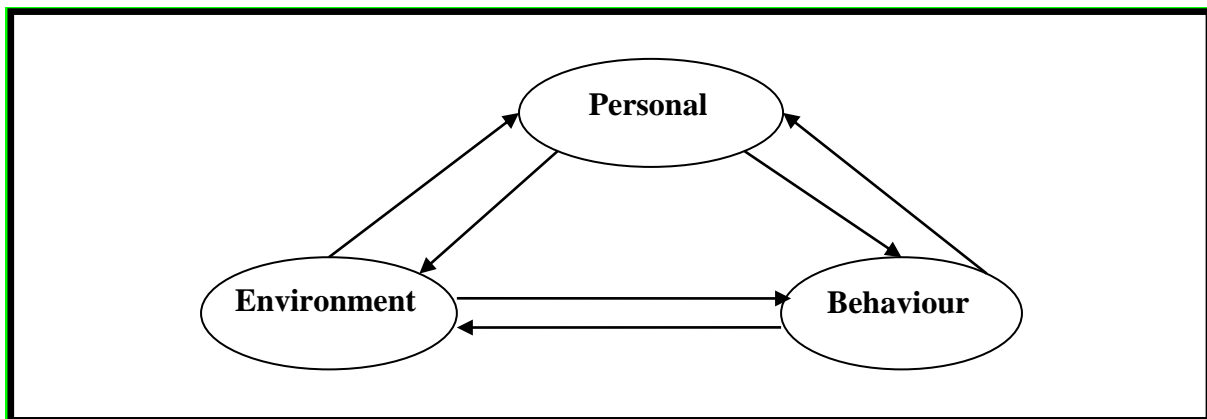


Figure 2. *Triadic Process of Self-Regulation* (Zimmerman, 2000)

As seen in Figure 2, human being is the result of an interdependent causal structure of the personal (e.g., beliefs, motivation), environmental (e.g., classroom), and behavioral (e.g., self-regulation) factors. These three aspects are the determinants of self-regulated learning. Bandura (1986) explains that these aspects are causally interrelated. Namely, when a person attempts to self-regulate, the result is his performance or behavior, and this behavior affects his environmental change.

Although there is no simple and straightforward definition of self-regulation, the theory of educational psychology has narrowed the scope of students' self-regulated abilities to the academic side of education, i.e., learning objectives and academic achievement (Boekaerts & Corno, 2005). Researchers, in particular, argue that self-regulated ability is central to the educational assumptions of learning, decision-making, problem-solving, and resource management. Furthermore, Carver and Scheier (1990) depict that self-regulation is a complex system, a set of superordinic functions located at the crossroads of several psychological studies on cognition, problem solving, decision making, metacognition, conceptual change, motivation, and volition. Additionally, Zimmerman (2002) defines self-regulated learning as the degree of metacognition, intrinsic motivation and individual behaviors in the learning process. Wolters (2003) states that self-regulated learning, which engage students in actively constructing their learning processes, fosters them to to monitor, organize, and control their cognitive, motivational, and behavioral issues. In fact, goals direct and drive these issues to prioritize the environmental context. To sum up, self regulation requires students to actively engage in learning process by monitoring, controlling, and evaluating the use of cognition, motivation, and behavior through learning goals.

c) Students' Beliefs and Self-Regulated Strategies in Physics Learning

As mentioned above, beliefs as a multidimensional system (Schommer, 1990) initiate the development of research exploring the relationship(s) between epistemological beliefs and various aspects of student learning, i.e., academic achievement (Muis, 2007; Savoji, Niusha, & Boreiri, 2013), learning environment (Velayutham, Aldridge, & Afari, 2013), and self-regulation (Bråten & Strømsø, 2005; Greene, Muis, & Pieschl, 2010). Meanwhile, Hammer and Elby (2002) also developed a model called the epistemological belief resources given Schommer's (1990) framework. This model explains that students' beliefs of learning are highly dependent on the context (e. g., physics, mathematics, social, etc.). Hammer (1994) classified students' beliefs of physics and physics learning into three dimensions, namely beliefs about the structure of physics, the content of physics knowledge, and the learning process in physics.

A few studies have attempted to analyze the correlations between students' beliefs of learning and self-regulation. Muis and Franco (2009) found that epistemic beliefs influenced the types of learning strategies used by students in the introductory educational psychology course, and achievement goals mediated relations between epistemic beliefs and learning strategies. Dahl, Bals, and Turi (2005) analyzed the relationship between students' beliefs of knowledge and learning with the use of learning strategies in understanding text. Their results proved that students' beliefs of knowledge structure and innate ability significantly contributed to the use of learning strategies. Students, who believed that knowledge was a collection of facts isolated from each other (simple knowledge), tended to use rehearsal learning strategies (repeat) rather than organizational strategies. While students, who believed that learning was an innate ability, tended to rarely use elaboration strategies and critical thinking. Students with naïve belief tended to learn with superficial strategies (e.g., rehearsals) and failed to connect their prior knowledge with new learned one. Also, these students were reluctant to use critical thinking skills in processing information. On the other hand, Bråten and Strømsø (2005) elicited that preservice teachers' beliefs of knowledge construction and modification were a better predictor for self-regulated learning, while business administration students' beliefs of the certainty of knowledge played an crucial role in self-regulated learning. However, none of these studies has investigated the relationship(s) between students' beliefs and their self-regulated learning of physics learning. Therefore, this study purposed to fill in an important gap in the related literature, especially physics education. This study aimed to explore preservice science teachers' beliefs of physics and physics learning, and to examine the relationship(s) between their beliefs and self-regulated strategies (rehearsal, elaboration, organization, critical thinking, and metacognitive) in studying physics.

METHODOLOGY

a) The sample of the study and instruments

A total of 248 students were drawn from physics education at one state and one state Islamic universities in Jambi, Indonesia. All participants were asked to sign a consent form to participate in this study. Hence, only participants who signed the consent form and were willing to take part in the current study, involved in the sample of the study. Prior to the analysis, the researchers firstly performed cleanup data. The researchers reviewed students' responses on each item to check any unfilled one and re-rank any negative item. This preliminary process finally generated 244 valid responses for running the next analysis stage. Table 1 summarizes the sample's demographic information.

Table 1. *Participants' Demographic Information*

Datasetting	Gender		Age
	Male	Female	
Department of Physics Education -A	57	89	18 to 21
Department of Physics Education -B	39	63	

The researchers followed a two-stage test. The first test was the exploratory factor analysis (EFA) to measure students' beliefs of physics and physics learning using the Colorado Learning Attitudes about Science Survey (CLASS). The second test was the confirmatory factor analysis (CFA) to analyze the convergent validity of each sub-factor in the EFA test and examine the structural equation model on the relationship(s) between students' beliefs variables and self-regulated learning in studying physics. Since these analysis cannot use the same dataset (DeCoster, 1998), the researchers randomly split the data into two parts, named "odd" (for the exploratory factor analysis) and "even" data (for the confirmatory factor analysis).

In collecting quantitative data, the researchers used two questionnaires; (1) Motivated Strategies for Learning Questionnaire (MSLQ) to measure students' self-regulated strategies in learning (Pintrich, 1991), and (2) The Colorado Learning Attitudes About Science Survey (CLASS) to measure students' beliefs of physics and physics learning (Adams et al., 2006). To ensure the validity and reliability of the instruments for the Indonesian context, the CLASS and MSLQ questionnaires were firstly adapted into the Indonesian versions by means of several stages. In the first stage, the CLASS and MSLQ questionnaires were translated into Indonesian by two bilingual lecturers from the Department of Physics Education. Also, their feedbacks were employed to improve the translation procedure.

The next stage tested the obtained data using the factor analysis test within SPSS 22.0TM. Factor analysis allowed the researchers to determine whether multiple variables could be explained by several factors (Fraenkel, Wallen, & Hyun, 2011). The exploratory factor analysis was exploited in the current study with the main component analysis, varimax rotation for Eigen value > 1. Figure 3 outlines the flowchart of validation process of the CLASS and MSLQ questionnaires.

**Figure 3.** *Flowchart Validation Process of the CLASS and MSLQ Questionnaires*

b) Data Analysis

This study used data analysis with Partial Least Square-Structural Equation Modeling (PLS-SEM model) through SmartPLS version 3.0 software. SEM, which is a multivariate analysis, combines factor analysis with simultaneous path analysis. The SEM model integrates empirical data analysis into theoretical constructs. In this study, the ultimate goal of SEM was to obtain a structural equation model on the relationship(s) amongst students' learning environment, self-regulated strategies, and beliefs of studying physics.

FINDINGS

a) Measurement of Data Quality

This study used the Structural Equation Model (SEM) based variance (VB-SEM) with the Partial Least Square Path Model (PLS-SEM) technique. The PLS approach, which is an Asymptotic Distribution Free (ADF), means that the data do not have a certain distribution pattern, and are nominal, category, ordinal, interval, and ratio. The minimum number of the sample for PLS-SEM is ten times, and the largest number of structural paths directed at specific latent constructs in the research model (Chin, Marcolin, and Newsted, 2003). Based on these rules, the number of the sample was 50 respondents for the present study. The sample of the present study (248 respondents) was more than the number suggested by Chin et al. (2003) and met the PLS model.

b) CLASS Questionnaire Validation Using Exploratory Factor Analysis

The results of the CLASS' factor analysis using the principal component analysis with the orthogonal rotation (varimax) yielded into two factors of their beliefs with the total variance of 31.003%. The initial assumption test showed the value of Kaiser-Meyer-Olkin of 0.693 with a significance value of 0.00. Both values ($KMO > 0.5$ and significance of Bartlett's Test of Sphericity < 0.05) met the initial requirements for the factor analysis (Pallant, 2013). The screenplot analysis shows the fractures after two factors (see Figure 4).



Figure 4. Screen Plot Data

As can be seen from Figure 4, the researchers decided two factors. The first factor consisted of items 9, 15-17, 23-25, while the second one comprised of items 4, 14, 15, 19, 21 and 26. Loading factor and reliability components are presented in Table 2.

Table 2. *Summary of Exploratory Factor Analysis and the Reliability of the CLASS Questionnaire for 2 Components*

Items	Components	
	1	2
23	0.544	
16	0.540	
17	0.534	
9	0.497	
24	0.478	
15	0.469	
25	0.467	
26		0.660
21		0.623
19		0.541
14		0.537
15		0.514
4		0.514
Eigenvalue	3.104	2.651
% Variance	12.417	10.602
Cumulative %	12.417	23.019
Reliability	0.631	0.598

c) Convergent Validity Using Confirmatory Factor Analysis (CFA)

The next step analyzed the convergence and discriminant validities of the CLASS questionnaire using 13 items from EFA. The researchers also checked the convergence validity of the MSLQ. Item reliability can be seen from the standardized loading factor, which describes the magnitude of the correlation between each item (indicator) and its latent construct. The loading factor value ≥ 0.7 is an ideal indicator for the construct validity (Chin, 1998; Hulland, 1999). Siswoyo (2015) views the loading factor value ≥ 0.5 as an acceptable value. Thus, the loading factor value ≤ 0.5 must be dropped from the research model. The CFA results showed that several items had lower loading factor values than 0.5 based on a total of 13 items in the CLASS questionnaire. Hence, Because items 3, 12-14, 19-21, 23, 27, and 36 were dropped from the model, six valid items of the CLASS questionnaire were categorized into two dimensions, namely problem solving (3 items), and personal interest (3 items). Item loadings, composite variance, and average variance extracted of each dimension of the CLASS and MSLQ are shown in Table 3.

Table 3. *Item Loading Factors for the CLASS dan MSLQ Questionnaires*

Construct	Item	Loading Factor
Sophisticated Beliefs	SB19	0.814
	SB21	0.776
	SB26	0.738
Naïve Beliefs	SB15	0.894
	SB17	0.642
	SB23	0.654
Rehearsal	RH39	0.796

	RH46	0.632
	RH59	0.719
Elaboration	EL53	0.661
	EL64	0.787
	EL67	0.693
	OR32	0.738
Organization	OR42	0.875
	OR63	0.518
	CT38	0.669
Critical Thinking	CT47	0.806
	CT51	0.717
	CT71	0.662
Metacognitive Self Regulation	MT41	0.728
	MT78	0.679
	MT79	0.777

The internal consistency in PLS-SEM analysis can be seen from Cronbach's alpha and composite reliability (CR) values. The composite reliability to measure internal consistency is better than Cronbach's Alpha because CR does not assume the boot similarity of each indicator. The composite reliability boundary value is equal to Cronbach's Alpha ≥ 0.7 . The higher CR value means the higher construct contribution to the measurement model. The composite reliability of each latent construction of this study is displayed in Table 4.

Table 4. Internal Consistency Values of the CLASS dan MSLQ Questionnaires

Construct	Internal Consistency Values
Sophisticated Beliefs	0.820
Naïve Beliefs	0.779
Rehearsal	0.761
Elaboration	0.758
Organization	0.762
Critical Thinking	0.807
Metacognitive Self Regulation	0.772

The last criterion of convergent validity is the average variance extracted (AVE) measurement for each construct. The AVE value describes the variant or diversity of the manifest variables that the latent construct can have possesses (Siswoyo, 2015). Fornel and Lecker (1981, cited in Ghozali, 2008) recommend a minimum of 0.5 AVE for a good convergent validity.

Table 5. Average Variance Extracted (AVE) Value

Constructs	Average Variance Extracted (AVE) Values
Sophisticated Beliefs	0.603
Naïve Beliefs	0.546
Rehearsal	0.517
Elaboration	0.512
Organization	0.526
Critical Thinking	0.512
Metacognitive Self Regulation	0.531

d) Evaluation of Structural Model

Gefen, Straub, and Boudreau (2000) define two non-parametric methods for testing the relationship between the latent variables (bootstrap and jackknife). In this study, the researchers used the bootstrap method by evaluating the value of R² and t statistic generated from calculating output of PLS Bootstrapping. The influence between construct (s) and interaction effect (s) (moderation) was measured by the value of the coefficient path (path coefficient). Path coefficient, which has a t statistic value ≥ 1.96 or p-value ≤ 0.05 , indicates a statistical significance. The coefficient and t-value path for each hypothesis of relationship ways are shown in Table 6.

Table 6. *Coefficient Path Values*

Hypothesis of relationship way	Original Sample (O)	T Statistics (O/STDEV)	P Values	Conclusion
Naïve Beliefs -> Critical Thinking	-0.184	1.308	0.191	Not significant
Naïve Beliefs -> Elaboration	-0.258	2.522	0.012	Significant
Naïve Beliefs -> Metacognitive	-0.193	1.957	0.051	Not significant
Naïve Beliefs -> Organization	-0.154	0.920	0.358	Not significant
Naïve Beliefs -> Rehearsal	-0.233	2.188	0.029	Significant
Sophisticated Beliefs -> Rehearsal	0.214	1.859	0.064	Not significant
Sophisticated Beliefs -> Organization	0.246	2.405	0.017	Significant
Sophisticated Beliefs -> Elaboration	0.296	3.092	0.002	Significant
Sophisticated Beliefs -> Critical Thinking	0.163	1.302	0.193	Not Significant
Sophisticated Beliefs-> Metacognitive	0.264	2.368	0.018	Significant

DISCUSSION

This study aimed at analyzing the structural relationship between students' beliefs and self-regulated strategies in physics learning. The CLASS questionnaire by Adams, Perkins, Dubson, Finkelstein, and Wieman (2004) was used to measure their beliefs of physics and learning physics. The CLASS questionnaire was adapted into the Indonesian version. The results of the EFA and CFA emerged six valid items categorized under two dimensions, namely sophisticated beliefs (3 items), and naïve beliefs (3 items). Sophisticated beliefs, which highlight students' views about the content and process of physics learning, emphasize conceptual understanding and the importance of re-constructing knowledge. Naïve beliefs view physics as a collection of formula. In view of naïve beliefs, the best way to learn physics is to memorize many formulae. The composite reliability values for these belief dimensions (problem-solving ability and personal interest) were 0.820, and 0.779 respectively. The Indonesian version of the CLASS questionnaire was different from its original version by Douglas et al. (2014). As a matter of fact, Douglas et al. (2004) obtained three components from the explanatory factor analysis (EFA); personal application and real-life relation,

problem-solving/learning, and effort/sense-making. Such a difference may result from different cultures and the number of varied samples. For instance; Douglas et al. (2014) studied with 3,844 students, who completed basic physics courses at Purdue University, while the present study involved in only 248 students. That is, the number of the sample might affect the reliability values of each belief components. An increase in the number of the sample might result in the better reliability value of the instrument.

The Motivated Strategies for Learning Questionnaire (MSLQ) was conducted by using the confirmatory factor analysis (CFA). The MSLQ consists of 5 components measuring students' self-regulated strategies in learning (rehearsal, elaboration, organization, critical thinking, and metacognitive self-regulation). Each component consists of 4-8 items. Based on the convergent and discriminant validities of the MSLQ, several items were dropped from the model. The CFA results yielded 15 items that are divided into five components (3 for each component). The other items, which had a loading factor value of ≤ 0.5 , were excluded from the model. The five components of self-regulated strategies in the current study are consistent with Pintrich's (1991) ones.

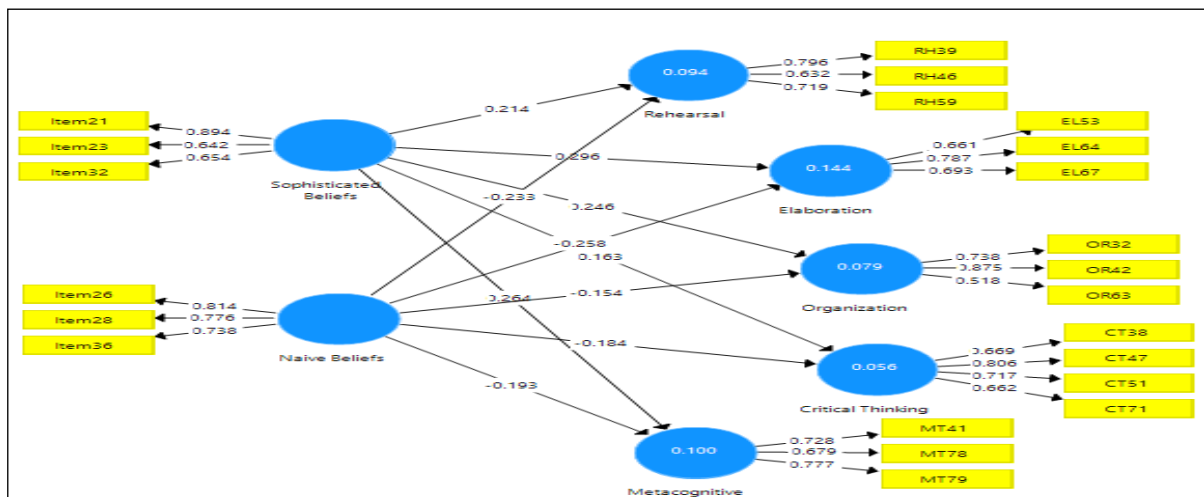


Figure 5. Structural Equation Model on Students' Structural Beliefs and Self-regulated Strategies

The structural equation model on the relationship(s) between students' beliefs, and self-regulated strategies in physics learning looked at the significance of the relationship between constructs shown by the value of t statistic output of bootstrapping if the value of t statistic ≥ 1.96 and the value of p value ≤ 0.05 exists. The structural equation model showed a positive and significant correlation between students' beliefs and self-regulated strategies in physics learning although these positive and significant correlations were not available for all scales of research variables. The results showed that sophisticated beliefs were positively correlated with the use of elaboration, organization, and metacognitive strategies, whereas the naïve beliefs were related with the use of rehearsal and elaboration strategies. These findings are a parallel with those of earlier studies. Students with the sophisticated beliefs, who understand the characteristic and construction process of physical knowledge, are able to monitor, evaluate, and improve the learning process. Previous researches indicate that students with the naïve beliefs, who fix, unchange, and hand down knowledge, are negatively related to their self-regulatory use (Bråten & Strømsø, 2005; Kortemeyer, 2007). Otherwise, students with the sophisticated beliefs realize that the best way to understand physics is to stress learning process on the conceptual understanding instead of memorizing the formulae (Hammer, 1994a).

To sum up, belief, which is one of the internal factors, plays an important role in knowledge construction. How to use self-regulated strategies will, in turn, be used for learning process will be determined. Physics needs to be taught through the nature of physics. Physics is often taught as a memorizable collection of facts and formulaes, so that students' strategies of learning physics pay more attention to only memorize formulaes and problem solving algorithms. A meta-analysis by Madsen (2015) states that the physics teachers' teaching techniques have a positive impact on their students' beliefs from the naïve to the sophisticated ones.

CONCLUSION


This study aimed to explore the structural equation model of the relationship between preservice teachers' beliefs and self-regulated strategies of studying physics. 248 respondents were drawn from physics education at one state and one Islamic universities in Jambi, Indonesia. This study showed that sophisticated beliefs were positively correlated to the use of elaboration, organization, and metacognitive strategies. In contrast, naïve beliefs were positively correlated with the use of rehearsal and elaboration methods. In particular, the findings of this study revealed that belief was one of the inside factors playing an essential role in constructing knowledge, and governing students' self-regulated strategies for learning process of physics. This study not only carried out to achieve predetermined goals, but also offered an important contribution for science education, especially physics education. This study theoretically contributed to the literature that examines the role of student beliefs on acquiring knowledge and their relevance to the use of self-regulated strategies of studying physics. further, the current study methodologically used the structural equation model via the variance analysis or SEM with PLS to create a significant contribution to future researches. In brief, this study practically provided insights to educators, especially lecturers how to plan, design, and practice appropriate and effective pedagogical strategies to improve students' beliefs and self-regulated strategies in studying physics. The current study suggests that appropriate and effective self-regulated strategies affect students' academic achievement in studying physics.

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A Comparison of Teachers' and Students' Perceptions of the Factors Contributing to Poor Performance in Physical Sciences: A case of South Africa

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ABSTRACT

Students' poor performances of Physical Sciences are a major problem in South Africa, particularly the district of Motheo. Even though the Department of Elementary Education in South Africa has invested a great deal of money for Physical Sciences in the new curriculum called the Curriculum Assessment Policy Statement (CAPS) to train teachers through workshops and in-service education, students have not still been well performing for this subject. Studies have been conducted on reasons and possible solutions/treatments of students' poor performances in Physical Sciences, but little progression has been achieved yet. This study aimed at comparing the teachers and students' perceptions of the factors contributing to poor performance in Physical Science, and discussing how to improve such performance. The sample of the current study consisted of seventy nine grade 11 students and seven teachers selected via convenient sampling method. Within a quantitative research method, a survey research design was used. The teachers' and students' responses to the questionnaire were compared to find out whether they have similar perceptions of the factors contributing to poor performance in Physical Sciences. This study revealed that they had varied perceptions of the factors under investigation. For example; teachers regarded instructional language (English) and students' poor mathematical backgrounds as great contributors to students' poor performances, whereas students saw a lack of practical work as a great contributor to their poor performances in Physical Sciences. The teachers and students also suggested different ways on how to improve students' performances in Physical Sciences.

Keywords: Curriculum assessment policy statement, New curriculum, Physical sciences, Poor performance, Science Education, Science Teachers and Grade 11 students.

INTRODUCTION

Curriculum Assessment Policy Statement (2011) states that "Physical Sciences prepare learners for future learning, specialist learning, employment, citizenship, holistic development, socio-economic development, and environmental management" (p.8). "Physical Sciences play an increasingly important role in the lives of all South Africans owing to their influence on scientific and technological development, which are necessary for the country's economic growth and the social wellbeing of its people" (CAPS, 2011, p.8).



“Physical Sciences use scientific inquiry, application of scientific models, theories and laws to investigate physical and chemical phenomena in order to explain and predict events in the physical environment” (CAPS, 2011,p.8). “It also addresses the needs of society, and society must be able to understand the physical environment to be able to care for and benefit from it responsibly” (CAPS, 2011,p.8).

“Physical Sciences play an important role in society in terms of economic growth and the social well-being of its people, and prepare learners for future learning, specialist learning, employment, citizenship and environmental management” (CAPS ,2011, p.8).

O’Connell (2009, p.4) depicts that South Africa’s education system is facing a major challenge in increasing the number of matriculated students into Mathematics and Physical Sciences. The South African Government has invested a great deal of money in developing teachers’ and students’ skills and interests of Mathematics and Physical Sciences. The country has seen spectacular growth in secondary school enrolment since 1994, however, the focus has been shifting to empower the quality of education and an increase in the number of matriculated students, who have strong foundations in Mathematics and Science (O’Connell,2009).

The Minister of Basic Education, Angie Motshekga, addressed that the grade 12 class of 2016 saw a 72.5% pass rate – up from the previous year’s 70.7%. She further revealed that the Free State had surpassed the Western Cape as the best performing province in the country (i.e., a pass rate of 88.2%, up from 81.6% in 2015) (Matric, 2016). The results also revealed that students, who excelled in such “gateway subjects” as Maths and Science, were much lower than the expectation. In Science, 3.7% of students (a total of 7 043 students), who wrote the paper, earned a distinction (Matric, 2016).

Investigating teachers’ and students’ perceptions of the factors contributing to poor performance in physical sciences gives an opportunity to compare and advance their views with each other. Comparing the teachers’ views (N: 7) with the students’ ones (N: 49) gives a chance for the teachers to relate their experiences to explain the reasons of poor performance in physical sciences. Any similarity between teachers’ and students’ perceptions of poor performance in physical sciences provides valuable different experiences for schools. Improving teachers’ and students’ performances in physical sciences is more important than prescribing them. Involving the teachers as collaborators of any research would discover new ideas to help the students improve their results. In addition, taking ownership of these ideas would also be transformed into the learning process.

Perceptions of the factors contributing to poor performance in physical science

Tswanwani, Harding, Engelbrecht and Maree (2014), who focused on the teachers’ and students’ perceptions of the factors facilitating the students’ performances in Mathematics, found that such factors as students’ and teachers’ commitment and motivation, attitudes and self-concepts, career paths, perceptions of peers and teachers; and teachers’ perceptions of students influenced disadvantaged students’ decisions to persist and achieve in Mathematics. Makgatho (2007) (cited by Tswanwani et al., 2014) found that the factors contributing to the students’ poor performances of Mathematics and Physical Sciences included the teacher’s content knowledge, time management, teaching strategies, parent’s commitment to student’s education, student’s motivation and interest. This study compared students’ and teachers’ perceptions of the factors contributing to poor performance in Physical Sciences rather than the actual factors involved. Further, its interest concentrated their perceptions on how to improve their performances of this subject.

Lesotho, Khanyane, Mokuku and Nthathakane (2016) investigated perceived gender differences in science performance. The study indicated that students and teachers had

complicated views about which gender outperforms science. The study reported that the principals perceived boys as out-performing girls in this regard, and depicted such perceived performance reasons for gender differences as self-efficacy; attitudes towards science gendered thinking and aptitude; diligence and perseverance; home experiences and culture; language proficiency; socio-economic challenges; and the use of discussion as a learning strategy.

Mji and Makgato (2006) identified such direct influences on poor performance as teaching strategies, content knowledge and understanding, motivation and interest, laboratory usage, and the completion of the syllabus as well as such indirect factors as parental role and language.

In wealthier homes, students are better prepared for school because school learning is supported by the types of conversations between students and their parents, exposure to books, and the types of responsibilities and their expectations (Criticos, Long, Mays, Moletsane, Mityane Grosser & De Jager, 2012). For these students, both school and home are functionally well in terms of learning. Students come into school very differently prepared for learning formal school knowledge. Many poor students come from homes that cannot always support what they have learned at school (Criticos et al., 2012). Bernstein calls the home as a second site of acquisition, the first being school. As a matter of fact, Aslan (2017) denotes that students' attitudes towards chemistry may influence their academic performance in the subject, their decisions and behaviours within the chemistry content.

Many students have only one site of acquisition (school). Parents may be illiterate and therefore unable to assist students with their school works. There may be few resources such as reading books, Internet or encyclopedias to assist learning. Students need unlikely to have a study desk or electricity at home to facilitate their doing homeworks at night.

Effective science teaching strategies in improving performance

The teaching strategies determining students' existing ideas and conceptions are important for teaching and learning of science (Çýmer, 2007). Hipkins et al. (2002) (cited by Çýmer, 2007) argue that effective science teaching requires students' pre-knowledge, values and beliefs that need to be assessed and linked to students' everyday lives and classroom experiences. Çepni, Ülger and Ormanci (2017) found that prospective teachers tended to associate information with daily life and give examples from everyday life. Furthermore, they discovered that prospective teachers focused knowledge transfer on everyday life rather than feeling, seeing or understanding science that they encountered in everyday life (Çepni et al, 2017).

In view of Ausbel (1968), Witrock (1994), Mintzes, Wandersee and Novak (1998) (cited by Çýmer, 2007), effective teaching strategies need to progress from known knowledge to unknown one. Hence, teacher is able to plan subsequent teaching activities that will assist students in linking their pre-existing knowledge to the new one.

Such different teaching approaches as question-and-answer techniques, group discussions, brainstorming, debating ideas and performing experiments can be used to assess the students' existing knowledge (Hewson & Hewson, 1998; Çýmer, 2007). Students will change their conceptions if they are dissatisfied with their existing knowledge and become aware of any inconsistency between their pre-existing and new knowledge (Çýmer, 2007). Science teachers may use such different contemporary teaching strategies as peer interaction, to challenge the students' ideas (Posner et al., 1982; Littleadyke, 1998).

The majority of students easily learn conceptions in a way relating their sensory channels to audio and visual representations, pictures, charts, models and multimedia (Çýmer,

2007). Visual aids, which provide more concrete meanings than words, show interconnections and interrelationships between the ideas (Çýmer, 2007).

Table1. Pass percentages of Physical Sciences in the Free State Province

Year	AVARAGE	PASS PERCENTAGE
	32.51	44.04
2010	35.82	55.21
2011	39.93	66.58
2012	41.94	73.96
2013	39.45	69
2014	39.8	69.7
2015		

As seen in Table 1, the pass percentage of Physical Sciences in the Free State Province was 44.04 in 2010. These percentages increased from 2011 (55.21%) to 2013 (73.96%). However, this percentage reduced to 69% in 2014, whilst there was a slight increase (69.7%) in 2015.

Table 2. The pass percentages of Physical Sciences in the Motheo District

Year	AVARAGE	PASS PERCENTAGE
2010	35.04	48.67
2011	36.73	54.6
2012	40.93	69.35
2013	43.63	75.78
2014	39.86	67.7
2015	39.2	64.6

As observed in Table 2, the pass percentage of Physical Sciences in the Motheo District was 48.67 in 2010, which was the lowest of all years. The pass percentages increased from 2011 (54.6%) to 2013 (75.78%). However, the pass percentages decreased in 2014 (67.7%) and 2015 (64.6%). This trend has resulted in a concern on the reasons of decreasing rates in Physical Sciences.

The following questions guided the present study:

- (1) What are the teachers' and students' perceptions of the factors contributing to poor performance in physical sciences?
- (2) Is there any similarity between the teachers' and students' perceptions of the factors contributing to poor performance in Physical Sciences?
- (3) How can teachers and students improve their performances in physical sciences?

Theoretical Framework

This study used school effectiveness model as a theoretical framework to provide the research lens for data collection and data analysis. In view of Ghani, Siraj, Radzi and Elham (2011), the model comprises of input variables, process, context, temporary findings and outcomes (see Figure 1). This study views input variables as best-selected variable to be concurrently applied to the process variable. The temporary intermediate finding acts as a control process (Ghani et al. 2011). If the process variable is not executed or applied concurrently, the structure and culture of the school as an organization will not be

accomplished to redevelop (Ghani et al., 2011). Furthermore, to reach the consensus level among the process variables will call the school for re-implementing the practices of an effective school (Ghani et al, 2011). This kind of analysis is similar to Stoll and Fink's (1996) views of the effective school movement and school improvement (Ghani et al, 2011).

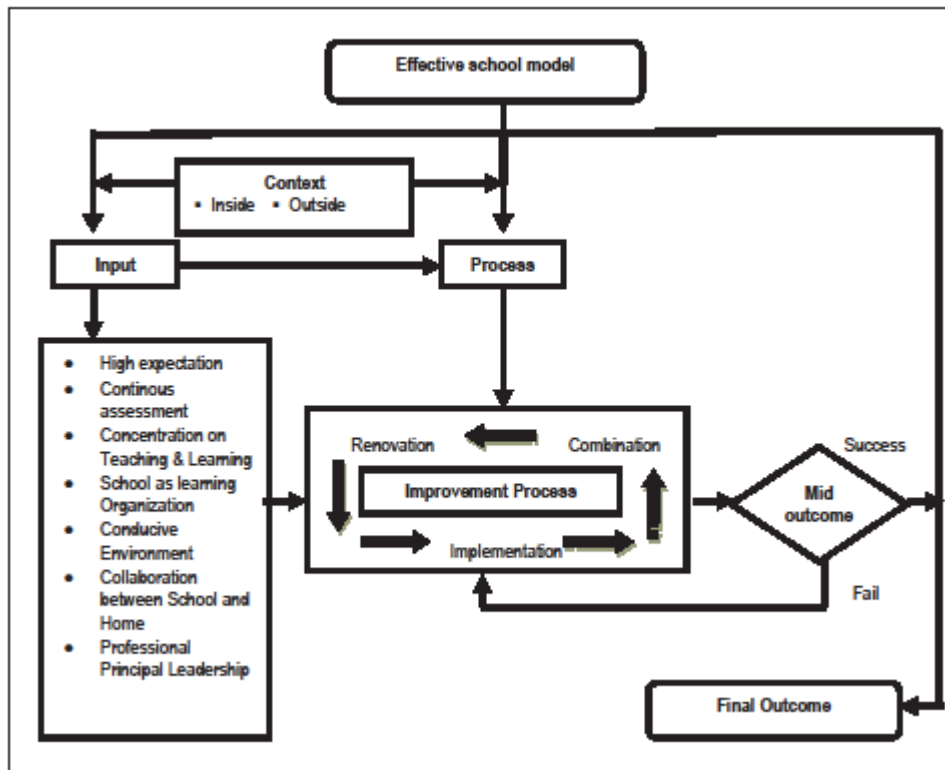


Figure 1. Effective school model of school effectiveness and improvement approach (Adopted from Ghani et al.2011).

ETHICAL CONSIDERATIONS

The researcher obtained official permission to conduct the study and asked the participants to get written consent forms before undertaking a research. The participants ethically remained anonymous for all questionnaires . All information was completely kept confidential.

METHODS

Within a quantitative research method, a survey design was used. Surveys aim to collect information as accurately as possible, and employ in such a way in repeating at another time or area, and comparable results(Lodico, Spaulding & Voegtle 2010). This study compared teachers' and students' perceptions of the factors contributing to physical sciences with each other.

a) Data Collection

Teachers' and students' perceptions of the factors contributing to poor performance in physical sciences were collected by means of a closed questionnaire. The questions about how to improve science performances were open-ended question. The questionnaire was pilot-studied to identify any ambiguity or unclear issue. Then, some questions in the questionnaire

were edited for clarity. Three questions adopted from Karigu (2015) were related to poor background in mathematics, lack of textbooks and teachers' poor teaching methods contributing to poor performance in physical sciences. The justification was to establish whether the students from different economic status and context would respond the same in three questions. The questionnaires of the teachers and students were somewhat different because some of the items were relevant to such factors as issues about job satisfaction, a lack of support from advisors and challenging content in CAPS for physical sciences. But, the closed questionnaires of the teachers and students generally covered factors about students, classrooms and schools.

A group of experts and peers in science education checked and validated the questionnaire .

b) Data Analysis

The data were quantitatively analyzed through such descriptive statistics as percentages and frequencies. Inferential statistics enabled to generalize the results from the sample data. , Since the questionnaire was the only instrument used to complement the captured data via the literature review, this study recruited this technique to gain insights of their perceptions. In analyzing the question about how to improve the poor results, the teachers' and students' responses to the questionnaires were exposed inference analysis.

c) The Population of the Study

The population of this study was all Grade 11 students and teachers from schools in the Motheo District.

d) The Sample of the Study

The sample of this study comprised of 79 Grade 11 students attending Saturday classes at a university of technology in South Africa. The aim of this intervention was to assist them in obtaining better results to continue Science, Engineering- and Technology-driven courses at higher education institutions. Enrolment in the study, which takes place annually in January, purposes to enable students to better prepare, and improve their marks for admission to Science, Engineering- and Technology-related courses in higher education institutions The convenient sampling technique was used to select seventy nine grade 11 students and seven teachers. That is, 46 (58.2%) female and 33 (41.8%) male students participated in the study. 74 (93.7%) of the students were from co-education secondary schools, while 5 (6.3%) of them were from female secondary schools.

32 (40.5%) of them were from secondary schools in rural areas, whilst 47 (59.5%) of them were from secondary schools in urban areas. 4 (57.1%) male and 3 (42.9%) female teachers took part in this study. 5 (71.4%) of the teachers were from co-education secondary schools, whereas 2 (28.6%) of them were from female secondary schools.. The focus on this skewed sample of the teachers and students was that this research only included volunteer participants involved a school –university intervention. Namely, this sample was more motivated and possessed higher science achievement than the average teachers and students in the same district.

FINDINGS

In this section, the findings gathered from the questionnaires and interviews conducted to reveal students' nature of science understandings were presented. In this

regard, four expected elements- being tentative, experiential, inferential, and imaginary and creativity, which the 5th-8th grade students have about the nature of science constituted their profiles. Additionally, to enhance the discussion that will be done about the students' nature of science understandings, the answers given to the questionnaire and the semi-structured interview were extensively explained by using direct quotations from the students' own statements.

Table 3 compares the students' and teachers' perceptions of the factors contributing to poor performance in Physical Sciences. The top numbers are for learners and the bottom are for teachers.

Table 3. Frequencies and percentages of students' and teachers' perceptions of the factors contributing to poor performance in Physical Sciences

Factor		Great extent		Lesser extent		Least extent	
		f	%	f	%	f	%
Lack of textbooks	Students	18	22.8-	22	27.8	39	49.4
	Teachers	-	-	3	42.9	3	42.9
Quality of Physical Sciences textbook	Students	16	20.3	33	41.8	30	38
	Teachers	1	14.2	1	14.2	4	57.1
The ratio of learner-teacher	Students	18	22.8	26	32.9	29	36.7
	Teachers	2	28.6	4	57.1	1	14.2
Students' negative attitudes towards Physical Sciences	Students	27	34.2	30	38	20	25.3
	Teachers	2	28.6	2	28.6	3	42.9
Teachers' poor teaching methods	Students	20	25.3	26	32.9	31	39.2
	Teachers	2	28.6	2	28.6	3	42.9
Lack of practical laboratory lessons	Students	40	50.6	14	17.7	23	29.1
	Teachers	3	42.9	3	42.9	1	14.2
Students' poor mathematical background	Students	19	24.1	35	44.3	24	30.4
	Teachers	4	57.1	1	14.2	2	28.6
Family socio economic status	Students	11	13.9	25	31.6	38	48.1
	Teachers	-	-	6	85.7	1	14.2
Non-completion of the syllabus	Students	26	32.9	24	30.4	26	32.9
	Teachers	3	42.9	2	28.6	2	28.6
English as an instructional language	Students	17	21.5	18	22.8	40	50.6
	Teachers	4	57.1	1	14.2	2	28.6
Lack of teacher's professional development	Students	17	21.5	28	35.4	30	38
	Teachers	2	28.6	2	28.6	3	42.9

40 (50.6%) of the students and three (42.9%) of the teachers perceived the lack of practical laboratory lessons as being a great contributor towards the poor performance in Physical Sciences. Four (57.1%) of the teachers and nineteen (24.1%) of the students regarded poor mathematical background as being a great contributor to the poor performance in Physical Sciences.

Four (57.1%) of the teachers regarded English as an instruction language as being a great contributor towards poor performance, while 40 (50.6%) of the students viewed English as an instruction language as a factor making the smallest contribution to poor performance in Physical Sciences. There is a disjuncture between teachers' and students' views of English as an instructional language. Perhaps this may result from the fact that most of the participants were students studying in urban areas, and some of whom attended former Model C schools. Four (57.1%) of the teachers and 30 (38%) of the students considered that the quality of the Physical Sciences textbook was not a great contributor to poor performance in the subject. This means that teachers' inabilities to assess the educational quality of a textbook.

Table 4 indicates the teachers' perceptions of poor performance that was apart from the students' questionnaires.

Table 4. Frequencies and percentages of the factors contributing to poor performance in Physical Sciences

Factors	Great extent		Lesser extent		Least extent	
	f	%	f	%	f	%
Challenging content in CAPS for Physical Sciences	5	71.4	2	28.6	-	-
Lack of advisor support	-	-	3	42.9	3	42.9
Job satisfaction	1	14.2	3	42.9	3	42.9

As seen from Table 4, the teachers saw the 'challenging content in the CAPS document for Physical Sciences' as being a great contributor to poor performance in Physical Sciences. Five (71.4%) of the teachers identified the 'challenging content in the CAPS document for Physical Sciences' as being a great contributor to poor performance in the subject. Perhaps this may come from a lack of in-service education on new topics contained in the CAPS document.

Table 5 illuminates the students' responses about how to improve their poor performances in Physical Sciences.

Table 5. Frequencies and percentages of the students' responses about how to improve their poor performances in Physical Sciences

Ways to improve poor performance	f	%
More extra classes in Physical Sciences	40	50.6
More practical lessons in Physical Sciences classrooms	52	65.8
Motivating students to have positive attitudes towards Physical Sciences	20	25.3
Use different teaching strategies in teaching Physical Sciences	15	19
Fully-equipped science laboratories	45	57
Relating physical science concepts to everyday life-experiences	12	20.3
Peer learning	24	30.3
Having more classroom activities than homeworks	14	17.7

As observed in Table 5, 52 (65.8%) of the students referred to more practical lessons in Physical Sciences classrooms. That is, most of the teachers maybe only doing experiments that are examinable.

45 (57%) of them cited to fully-equipped science laboratories. 40 (50.6%) of them depicted a need for more extra lessons in Physical Sciences, while 20 (25.3%) of them mentioned about a need for more motivation resulting in positive attitudes towards the subject. 15 (19%) of them suggested the use of different teaching strategies in teaching Physical Sciences. 12 (20.3%) of them reported to relate physical sciences concepts to their everyday life experiences. 24 (30.3%) of them stated that peer learning would improve poor performance in Physical Sciences, whereas 14 (17.7%) of them implied more classroom activities than homeworks.

Table 6 shows the teachers' responses regarding how to improve poor performance in Physical Sciences.

Table 6. Frequencies and percentages of the teachers' responses regarding how to improve poor performance in Physical Sciences

Ways to improve performance	f	%
More attention to science and mathematics concepts' basic principles	2	28.6
Avoiding code-switching resulting in more misconceptions	2	28.6
A need for more guidance and support to improve teachers' content knowledge and pedagogical content knowledge	4	57.1
A need of reasonable teacher-learner ratio for optimum interaction and attention	3	42.9
Training teachers about Natural Sciences at the GET band	4	57.1
Teacher consultation to realize problematic sections in Physical Sciences	2	28.6
Hands-on practical investigations in Physical Sciences classrooms.	2	28.6
A need for researching and reading a great deal of the topic teachers teach	1	14.2

As seen from Table 6, 2 (28.6%) of them cited to more attention to science and mathematics concepts' basic principles. 2 (28.6%) of them referred to avoid code-switching resulting in more misconceptions. 4 (57.1%) of them stated that teachers needed more guidance and support to improve their content knowledge and pedagogical content knowledge. 3 (42.9%) of them addressed a need of reasonable teacher-learner ratio for optimum interaction and attention. 4 (57.1%) of them implied training teachers about Natural Sciences at GET band. This may stem from the fact that most teachers only teach the topic they feel themselves comfortable to teach, e.g., a life science teacher will not do justice to the physical sciences a part of the 'natural sciences' syllabus.

2 (28.6%) of them pointed to teacher consultation to realize problematic sections in Physical Sciences. 2 (28.6%) of them dealt with hands-on practical investigations in the Physical Sciences classrooms. One (14.2%) student addressed a need for researching and reading a great deal of the topic teachers teach.

DISCUSSION

This study compared the teachers' and students' perceptions of the factors contributing poor performance in Physical Sciences. The results indicated that their perceptions of the factors were different. The teachers regarded 'challenging content in the CAPS document for Physical Sciences, English as an instructional language (Howie, 2003; Department of Education, 2000), and student's poor mathematical background' as great contributors to poor performance in physical sciences (Karigi et al., 2015). On the contrary to Karigi et al. (2015), this study did not find the 'lack of textbooks and poor teaching methods' as a great

contributor to poor performance in physical sciences. The students considered the ‘lack of practical laboratory lessons’ as a great contributor for poor performance in Physical Sciences (Mji & Makgato, 2006). Abraham and Rambuda (2000), Mosoeunyane, Torres and Zeilder (2002) (cited by Makgato,2007)saw the instructional language as a barrier for students’ performances in Mathematics and Physical Sciences. This study also found that English, as an instructional language, was a great contributor to poor performance in physical sciences. Tsanwani (2014) found teachers’ and students’ perceptions of the factors (student’s and teacher’s commitment and motivation, attitudes and self-conception, students’ career prospects, students’ perceptions of peers and teachers, and teachers’ perceptions of students) facilitating students’ performances in Mathematics. This study did not find students’ negative attitudes towards physical sciences as a great contributor to poor performance in physical sciences. Students suggested more practical lessons in physical sciences and fully-equipped science laboratories, whereas teachers recommended to more guidance and support for teachers to improve their content knowledge and pedagogical content knowledge and training teachers about natural sciences at the GET band.

CONCLUSION and RECOMMENDATIONS

The teachers’ and students’ perceptions of the factors contributing to poor performance were varied from one another. The teachers’ and students’ perceptions of the factors contributing to students’ poor performances in Physical Sciences were worrisome. They needed to be taken into cognizance by teachers and learners in order to improve their performances. Teachers and students should implement the suggested ways reported in the current study. Group or pair projects should be assigned to students to collaborate them outside of the classroom borders to enhance peer interaction. The school laboratories should be fully equipped. Teachers should try to conduct as many experiments as possible. Role models may also be invited to the school to motivate students. Workshops should regularly be conducted to help teachers challenge the content of the CAPS curriculum. To improve their content knowledge and pedagogical content knowledge teachers need more guidance and support. The department of basic education should employ teaching assistants to help students to do their homeworks. Teachers should didactically use contextualization to teach science. Hence, this will promote conceptual change and improve student’s poor performance in physical sciences.

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The Effects of Inquiry-based Learning Approach and Emotional Intelligence on Students' Science Achievement Levels

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ABSTRACT

The aim of this study was to examine the effects of inquiry-based learning approach and emotional intelligence on students' science achievement levels. Within a quasi-experimental research design (pre and post-test), the sample of the research comprised of 56 grade 7 students drawn from two classes at different schools in Binjai, Indonesia. In analyzing data, descriptive and inferential statistics through two-way ANOVA were used. The results of research revealed that the students, who attended inquiry learning approach (experimental group), acquired the highest science achievement. For the students with high emotional intelligence, the students, who were taught with the inquiry-based learning approach, possessed higher science achievement than did the conventional learning approach (control group). For the students with low emotional intelligence, the students, who were exposed to the conventional learning approach, had higher science achievement than did the experimental group. The results showed an interaction between the effects of learning approach and emotional intelligence on science achievement. Teachers need to use inquiry-based learning so that students' science achievements can be improved. In order for effective inquiry-based learning, the emotional intelligence of students needs to be improved.

Keywords: conventional learning approach, emotional intelligence, inquiry-based learning approach, science achievement.

INTRODUCTION

Science includes such four elements as process, product, attitude, and application (Sulistijo, Sukarmin, & Sunarno, 2017; Zubaidah, Fuad, Susriati & Suarsini, 2017). Students should learn science through investigation. Hence, they are able to get learning outcomes in the forms of facts, concepts, principles, theories, and laws (Subali, Humaidi & Aminah, 2018; Zeidan & Jayosi, 2015).

In view of Yarger and Penick (1990), learning science makes students achieve a high quality of life, overcome the existing social problems, develop their interests and talents towards science, and facilitate further science learning. People, who are sufficient knowledge of science, are good at transferring their scientific knowledge to other disciplines (Supriadi, 1994). Therefore, science should be taught earlier to the students in schools.

However, Preliminary studies have shown that learning science in junior high schools (SMP) in Binjai, Indonesia is still very poor level (Dinas Pendidikan Dasar, 2015). The



survey by Trends in International Mathematics and Science Study (TIMSS) showed that the quality of Indonesian science education fell into the 45th position among 48 countries in Asia, Africa and Australia (TIMSS, 2015). Furthermore, the average test score of science was 60.43 of 100. A low science achievement may result from teacher-centered instruction instead of student-centered one (Fuad, Zubaidah, Mahanal & Suarsini, 2015). This means that science learning should be well-designed / planned to improve students' science achievement.

One of the learning approaches improving students' science achievement is an inquiry-based learning. Yunus, Sanjaya, and Jatmiko (2013) showed that using inquiry-based physics learning improved students' science achievement of auditorics. Sağlam and Şahin (2017) and Abdi (2014) revealed that the inquiry-based learning approach was more effective in improving students' science achievement than conventional approaches. Setiawan et al. (2016) indicated that students, who were exposed to an inquiry-based learning, possessed higher science achievement scores than did those in the traditional instruction. The inquiry-based learning is effective in improving their science achievement levels, enthusiasms towards science practices/activities, and attitudes towards science learning processes (Setiawan, Sunarti & Astriani, 2016).

Such learning factors as interest, motivation, student engagement (Castro & Morales, 2017) and emotional intelligence (Woolfolk, 2004) influences science learning and/or achievement. Emotional intelligence is the ability to deploy emotional information appropriately and efficiently (Woolfolk, 2004). Goleman (1995) suggests that emotional intelligence predicts better academic success than traditional one. Several studies have shown that academic achievement is strongly associated with three dimensions of emotional intelligence, namely intrapersonal, adaptation, and stress management (Radfar, Aghaie, Arani, Nooh & Saburi, 2013; Fallahzadeh, 2011; Parker, Saklofske, Shaughnessy, Huang, Wood & Eastabrook, 2005). That is, there has been a significant relationship between emotional intelligence and academic achievement (Chew, Zain & Hassan, 2013; Noor & Hanafi, 2017).

Theoretical Background

a) Science Achievement

In view of Gagne and Briggs (1979), learning achievement is the acquired abilities (i.e., intellectual skills, cognitive strategies, verbal information, motor skills, and attitudes) after a learning process. Meanwhile, Reigeluth (1983) suggests that learning achievement is an observable behavior showing a person's ability. Bloom (1979) divides learning achievement into three domains, namely cognitive, affective, and psychomotor. The cognitive domain is related to learning goals, such as the ability to think, understand, and solve problems. The affective domain concerns on goals related to feelings, emotions, values, and attitudes showing acceptance or rejection of something. The psychomotor domain links to motor skills and manipulation of materials or objects.

Science is a discipline explaining the students' observation processes of nature (Ormrod, 2000). According to Carin and Sund (1989), science, which obtains data through observation and controls experiments via processes, products, and human attitudes, is a knowledge system about the universe.

Science refers to the methods and procedures as processes to acquire knowledge. The procedures are called the scientists' basic skills or abilities (science process skills) and generally consist of the following stages: (1) aware of the problem; (2) construct hypothesis; (3) conduct the experiment; (4) do the observation; (5) construct, collect, and analyze the data; (6) repeat the experiment for data verification; and (7) make a data-based conclusion (Carin & Sund, 1989). In point of Passe's (1999) view, science process skills can be divided

into two categories, namely basic and integrated process skills. The basic process skills include observation, classification, measurement, communication, inference, prediction, and interrelationships while the integrated ones contain formulating a hypothesis, identifying the variable, controlling variable, operationally defining variables, conducting the experiment, interpreting data, and investigation (Akgün, Özden, Çinici, Aslan, and Berber 2014; Yildirim, Çalik, and Özmen, 2016).

Science consists of a cumulative knowledge including facts, concepts, principles, laws, and theories, which are the results of human inventions/attempts to understand and explain nature and various natural phenomena. For elementary level, science materials are separated into three scientific fields: physical science, life science, and earth science. The physical science covers such non-biological phenomena as air, magnetism, electricity, and energy. The life science embraces such all living things as animals and human, plants, and the interaction(s) between plants, animals, and environment. The earth science includes astronomy, meteorology, and geology (Cain & Evans, 1990).

Science also contains a certain system of values and attitudes. In this case, the system of values and attitudes refers to the beliefs, opinions, and values that a scientist needs to seek and develop a new knowledge, such as responsibility, curiosity, discipline, diligence, honesty, and openness to the opinions of others (Carin & Sund, 1989).

b) Inquiry-Based Learning and Conventional Learning Approach

Inquiry-based learning approach consists of activities focusing on students' knowledge, skills, and attitudes that actively engage students in finding their own answers to a questionable problem (Dostal, 2015; Zubaidah, Fuad, Susriati & Suarsini, 2017). Although this approach has been modified several times since 1910, its elements have almost been the same. For example, a teacher presents any event via puzzles, questions, or problems. Then, students are able to: (1) formulate their own hypothesis to explain the event(s) or solve the problem(s); (2) collect data to test the hypothesis; (3) describe the conclusions; and (4) reflect new problems and think about any problem solving process (Woolfolk, 2004; Lashley, Matczynski & Rowley, 2002).

Accordingly, Burden and Byrd (2010) explained the following steps of inquiry-based learning approach: (a) identifying and formulating problems; (b) formulating hypothesis; (c) collecting data; (d) analyzing and interpreting data to test the hypothesis; and (e) describing the conclusions.

Inquiry-based learning approach is underpinned with a constructivist learning, in which students build an understanding by using their own worldviews or pre-existing knowledge. That is, since learning is an interaction between new and pre-existing knowledge, they construct their own conceptions through intellectual development activities (Burden & Byrd, 2010; Sağlam & Şahin, 2017).

Inquiry-based learning approach should be well-designed and organized, especially for students, who are not good at mastering science and problem solving. Several studies have shown that inquiry-based learning approach is less effective for lower-ability students (Corno & Snow, 1986; Woolfolk, 2004). The most efficient advantages of inquiry-based learning approach is that the subject and the process of investigation or discovery are taught at the same time (Woolfolk, 2004; Burden & Byrd, 2010).

Teachers act as a single source in the conventional learning approach meaning a teacher-centered instructional procedure (i.e, chalk and talk; a presenter of lesson content). This learning approach tends to outline content and lesson schedules that are delivered at the beginning of the lesson. That is, learning process includes some transparencies, paper sheets

with pictures, charts, and forms. Students listen instructional activities or take notes or fill in the exercise forms, or do tasks assigned by the teachers (Suparman, 1997).

In conventional learning activities, teachers give limited feedbacks to student tasks, use few resources and/or equipments. Namely, teachers are very dominant in using and selecting learning resources (Gerlach & Ely, 1971).

In view of Nasution (2000), conventional learning approach has such characteristics as: (1) lessons are presented to a group or class as a whole without considering individual differences; (2) presentation materials are mostly in the forms of lectures, assignments, written, and other medias; (3) an emphasis on the teaching process centered by the teacher; (4) passive students, who have to listen teacher's lecture; and (5) teacher primarily serves as the primary knowledge disseminator or distributor.

c) Emotional Intelligence

Emotional intelligence is a part of social intelligence that can motivate oneself, regulate emotions, encourage feelings of understanding, and use emotions effectively for arguing and solving problems, and increasing cognitive activities (Yildizbas, 2017; Mayer, Salovey, Caruso & Sitarenios, 2001).

Emotional intelligence is one's ability to motivate themselves, resist failure, control emotions, delay satisfaction, regulate psychological condition from areas of thinking, empathy, and hope (Goleman, 1995). Emotional intelligence is closely related to work success, quality of life, social experience, communication, learning achievement, cognitive functions, and processes of human (Bagheri, Kosnin & Besharat, 2016). There are five areas of emotional intelligence; (1) recognizing emotions; (2) managing emotions; (3) self-motivating; (4) recognizing the emotions of others; and (5) maintaining relationships with others (Goleman, 1995).

Several researches have shown that emotional intelligence has a significant relationship with academic achievement and performance (Bagheri, Kosnin & Besharat, 2016). People, who have high emotional intelligence, are more fortunate and successful in their personal and professional lives (Yildizbas, 2017) and happy, healthy psychologically, and social networks (Furnham, & Petrides, 2003; Austin, Saklofske & Egan, 2005).

d) Research Aim

The aim of this research was to examine the effects of inquiry-based learning approach and emotional intelligence on students' science achievement levels.

METHODS

a) Model of Research

Within a quasi-experimental research design, the current study sought the effects of the independent variables (inquiry and conventional learning approaches; and emotional intelligence--high and low) on the dependent variable (science learning achievement). A 2 x 2 factorial experimental design is presented in Table 1.

Table 1. Factorial Design 2 x 2

Emotional Intelligence (I)	Learning Approach (S)	
	Inquiry (S ₁)	Conventional (S ₂)
High (I ₁)	I ₁ S ₁	I ₁ S ₂
Low (I ₂)	I ₂ S ₁	I ₂ S ₂

b) Research Procedure

Prior to the research, the teachers, who would teach the topic to the experimental group, were trained about inquiry-based learning approach. Researchers also gave the topic, teaching objectives, and instructional media for a eight-week treatment. Meanwhile, teachers, who would instruct the topic to the control group, were only given topic and teaching objectives for an eight-week treatment. Meanwhile, teachers at both groups had similar topic and teaching objectives. For the first week, students in both groups were exposed to an ‘emotional intelligence’ questionnaire. This questionnaire was used to determine the students’ levels of emotional intelligence and to divide them into high and low categories. Then, the experimental group attended to inquiry-based learning approach for the other weeks, whilst the control groups was exposed to conventional learning approach. The researcher also observed all learning processes in the experimental group to make sure the extent to which the teachers followed all prepared instructional stages. The researcher also observed the control group for four times in order to confirm teachers’ use of conventional learning approach.

In the experimental group, the teachers introduced the topic and explained objectives to students. Then, they were divided into small groups of 4 or 5. Teachers guided students to identify and formulate related problems and hypotheses. They also facilitated students to design the data collection instruments and guided them to analyze and test their hypotheses. They were then asked to draw their conclusions. Next, they were asked to present their works. The teachers helped them to revise somethings if necessary. Finally, the teachers evaluated their understanding of the topic under investigation throughout their group presentations. At the end of the lesson, they were requested to revise the topics they had learned. These procedures were repeated for 6 weeks (three times a week).

In the control group, the teachers introduced the topic and discussed the topic using textbooks and other teaching props. Next, their understanding levels were evaluated by asking questions. Then, the teachers concluded their classes. Those procedures lasted 6 weeks (three times a week). The topic and duration in both groups were the same.

c) The Sample of Research

The population of this research was all 7th-grade students in the junior high school, Binjai, Indonesia. After the homogeneity test was done, the students drawn from SMP 3 Binjai were assigned as the control group (conventional learning approach). The students selected from SMP 4 Binjai, Indonesia, were devoted to the experimental group (inquiry-based learning approach). The sample of the study consisted of 56 students (28 by 28 for high and low emotional intelligence). Each of the four groups involved in 14 high and 14 low emotional intelligence students (see Table 2).

Table 2. The sample of the study in regard to place and type of treatment

Places and types treatment	SMP 4	SMP 3	N
	Inquiry-based learning	Conventional learning	
Emotional intelligence			
High	14	14	28
Low	14	14	28
Total	28	28	56

This research was conducted in period of August – November 2016. The science topics comprised of objects of science and its observations, classification of living things and matter, temperature and heat, and their changes.

d) Research Instrument

The researcher used a post-test to measure the students' science achievement levels and an 'emotional intelligence' questionnaire. The pre- and post-tests consisted of 50 multiple choice questions. Two experienced science teachers (teaching science more than 9 years) checked and validated the post-test's questions and answers. To avoid any research bias, the teachers were selected from other schools, apart from the sample schools. The reliability coefficients for the multiple choice questions were found to be 0.81 (KR-21) and 0.84 (KR-20). This means that the questions were reliable.

The 'emotional intelligence' questionnaire consisted of 30 Likert-type items. The researcher adopted 30 items from the questionnaire used by Karmila (2014) and modified them in regard to the objectives of the current research. The questionnaire was ranged from 'absolutely agree' (4 points) to 'absolutely disagree' (1 point). A total score of each student was handled to represent their interests.

Prior to the actual study, a pilot study was conducted with 32 students in a junior high school, in Binjai, Indonesia. The pilot study showed that the instructional materials/documents and data collection instruments were understandable. Cronbach's Alpha value for the questionnaire was found to be 0.721, which is higher than the acceptable value (0.60) suggested by Sekaran and Bougie (2013). The obtained data were analyzed using two-way ANOVA (analysis of variance).

e) Data Analysis

Within a 2x2 experimental factorial design, two-way ANOVA (Creswell, 2008) examined the effect(s) of the main and interaction factors by classifying variables into two approaches (inquiry-based and conventional learning). A moderator variable was categorized into low and high emotional intelligence. In data analysis, the requirements for the statistical analysis were tested with the normality (One-Sample Kolmogorov-Smirnov Test) and homogeneity (Levene's Test of Equality of Error Variances) tests.

If the results of the variance analysis show an interaction between independent and dependent variables, the post-hoc variance analysis with Tukey's test or Tukey's Honestly Significant Difference (HSD) appears (Ferguson & Takane, 1989; Kirk, 1982) to test the research hypothesis in depth.

FINDINGS

The hypothesis of this research were: (1) there was a significant difference between two learning approaches' mean scores of science learning achievement; (2) there was an interaction between the effects of the learning approaches and emotional intelligence on the students' science learning achievement levels; (3) the science learning achievement of the students, who were exposed to the inquiry learning approach and possessed high emotional intelligence, were higher than those taught with the conventional approach; (4) the science learning achievement of the students, who were taught with the inquiry-based learning approach and had low emotional intelligence, were lower than those instructed with the conventional learning approach. The data were analyzed with Statistical Package for the Social Science (SPSS) 22.0TM. The statistical test requirements for the analysis of this

research were confirmed with normality (One-Sample Kolmogorov-Smirnov Test) and homogeneity (Levene's Test of Equality of Error Variances) tests (see Table 3).

Table 3. The Results of the Normality and Homogeneity Tests

Data Groups	Normality		Homogeneity	
	N	Sig.	Levene's Test Score	Sig.
Post-test of the science learning achievement	56	0.719	0.892	0.451

As can be seen from Table 3, the data of the current study were normally distributed and all variances were homogeneous ($p > 0.05$).

The results of two-way ANOVA are presented in Table 4.

Table 4. The Results of Two-Way ANOVA

Source	Sum of Squares	df	Mean Square	F	Sig.
Learning Approach	423.500	1	423.500	5.511	.023
Emotional Intelligence	1.786	1	1.786	.023	.879
Learning Approach*Emotional Intelligence	3301.786	1	3301.786	42.963	.000
Within Groups	997.05	52	18.14	-	-
Total of Reduction	1928.82	55	-	-	-

As seen in Table 4, the first and second hypothesis of the current study were accepted. Regarding the second hypothesis of the current study, Tukey test was performed to test any difference between the mean scores of two paired groups via HSD critical value (honestly significant difference) (see Table 5).

Table 5. The Results of Two-Way ANOVA with Post-hoc Tukey Test

Paired Groups	Mean Difference Value (q_0)	Degrees of Freedom (df)	HSD Critical Value (q_t)	Description
I ₁ S ₁ and I ₁ S ₂	17.09	4;52	4.03	Significant
I ₂ S ₁ and I ₂ S ₂	8.08	4;52	4.03	Significant

As seen in Table 5, the results of post-hoc two-way ANOVA with Tukey test accepted the third hypothesis. The results of Tukey test indicated the critical Q value to be 17.09 and the Q table value to be 4.03. Thus, the fact that the critical Q value was higher than the Q table one rejected H_0 , and accepted H_1 . The fourth hypothesis was also accepted. The results of Tukey test calculated the critical Q value to be 8.08 and the Q table value to be 4.03. Thus, the fact that the critical Q value was higher than the Q table one rejected H_0 , and accepted H_1 .

DISCUSSION, CONCLUSIONS and IMPLICATIONS

A significant difference between different learning approaches' mean scores of science achievement may result from features of the inquiry-based learning approaches. That is, mean scores of the inquiry-based and conventional learning approaches' science achievement levels were found to be 60.86, and 55.36 respectively.

This result is consistent with Setiawan, Sunarti, and Astriani's (2016) statement. That is, the inquiry-based learning approach is more effective in improving students' science achievement than does the conventional learning (Abdi, 2014; Castro & Morales, 2017; Subali, Humaidi & Aminah, 2018). A significant difference between students' science achievement levels may come from the inquiry-based learning approaches.

This result supported Prince and Felder's (2006) view addressing that an inquiry-based learning approach is efficient in improving students' academic understanding and science achievement.

Secondly, an interaction between the effects of learning approach and emotional intelligence on the students' science achievement levels may stem from the inquiry-based learning approach facilitating better science achievement than conventional learning approach. In contrast, the students with low emotional intelligence showed a lower science achievement with inquiry-based learning approach than conventional learning approach. This is in line with Hastuti and Panjaitan's (2014) result implying an interaction between the effects of learning strategies and emotional intelligence on students' learning achievement levels.

An interaction between the effects of the learning model and emotional intelligence on students' learning outcomes is consistent with the result of Amin, Nuriah and Sarkadi (2017). The effectiveness of the learning approach is related with students' characteristics (Burden & Byrd, (2010) herefore, teachers need to understand their students' characteristics to determine the best learning approaches for their students.

Thirdly, the students, who had high emotional intelligence, and attended the inquiry-based learning approach, had higher meanscore of science learning achievement (68.71) than did the conventional learning approach (47.85). This means that active learning approaches (i.e., cooperative and inquiry approaches) engaging students in the learning process are more appropriate for students with high emotional intelligence (Amin, Nuriah & Sarkadi, 2017; Hastuti & Panjaitan, 2014).

Because students with high emotional intelligence have such characteristics as self-motivation, optimistic, independent, high thinking ability, empathy, personal goals, and responsible (Joshi, Srivastava & Raychaudhuri, 2012; Stewart, Chisholm & Allen, 2010; Goleman, 1995), employing learning motivation to success and individual responsibility seems to be essential factors supporting the effectiveness of the inquiry-based learning approach in practicum. Both factors would encourage students to help each other during the learning process. Conversely, if two factors are absent, students will not be interested in improving their learning achievement levels (Burden & Byrd, 2010). This is in accordance with Slavin's (1995) two necessary factors to obtain academic achievement: group goals (motivation to success) and individual responsibility. In addition, learning approach engaging students actively in learning process (i.e., inquiry based learning strategies), particularly for science, is more effective than the traditional or conventional learning approach (Bredderman, 1983).

Fourthly, the students with low emotional intelligence, who were taught by the inquiry-based learning approach, had a lower mean score of science learning achievement (53.00) than did the conventional learning approach (62.85). This means that using a conventional learning approach is more effective for the students with low emotional intelligence because

this approach does not require teamwork, giving learning responsibility to students and challenging to science learning (Amin, Nuriah & Sarkadi, 2017; Hastuti & Panjaitan, 2014). Students with low emotional intelligence will easily follow learning process facilitated by the teacher by. In other words, it can be deduced that the inquiry learning approach is not effective for the low-ability students and low-emotional intelligence (Woolfolk, 2004).

Students with low emotional intelligence take less learning responsibility through active learning processes and show less self-confidence in completing learning tasks. These characteristics need to be guided by teachers during learning process. According to Burden and Byrd (2010), students learn basic skills quickly throughout teachers' directions and explanations in the conventional learning approach. This is in a harmony with Suprihatiningrum's (2016) statement depicting that the conventional learning approach is useful for students with low self-confident and skills in doing their tasks.

In light of the results, it can be concluded that the inquiry-based learning and conventional learning approaches significantly impact the students' science learning achievements. In fact, the inquiry-based learning approach seems to have highly influenced students' science learning outcomes.

An interaction between the effects of learning approach and emotional intelligence on the students' science learning achievement levels revealed that the inquiry-based learning approach is more effective for the students with high emotional intelligence. On the contrary, it can be concluded that the conventional learning approach is more efficient for the students with low emotional intelligence.

Based on the findings of this study, the researcher recommends the implementation of inquiry-based learning, especially in science subjects, to improve students' science achievement. Students' science achievement need to be improved so that students have a high quality of life, can solve social problems, can develop their interests and talents, and can adapt to the development of science and technology needed in the 21st century. In addition, students' emotional intelligence needs to be improved so that inquiry-based learning can be implemented effectively.

Because this study is only limited to science subjects in junior high schools, further researches should be undertaken on different subjects in primary and/or senior high schools. Furthermore, future researches should focus on the learning outcomes of other subjects, such as mathematics, geography, and history.

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The Effect of Conventional Laboratory Practical Manuals on Pre-Service Teachers' Integrated Science Process Skills

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ABSTRACT

This study explored the effect of conventional laboratory practical manuals on pre-service teachers' integrated science process skills (ISPS). A validated multiple-choice questionnaire with the ISPS components was used to collect data. No significant difference between pre-service subject-specific teachers' (biology, physics and chemistry) ISPS scores was found. The ISPS scores significantly increased along with proliferation in lab practical works, except for physics. Pre-service math teachers, who had no lab practical works, showed significantly higher ISPS scores than pre-service science teachers. The results indicated that all pre-service teachers' ISPS scores fell into intermediate level. Further, it was found that they possessed the lowest scores for such ISPS as identifying and controlling variable, stating operational definition and designing experiments. The common format of the conventional laboratory manual adopted from many universities need to be reformatted for engage learners in all ISPS. To improve learners' ISPS, higher-order thinking assignments should be intensively given to them.

Keywords: assessment, inquiry, science subject, laboratory manual, mathematics

INTRODUCTION

Scientific research processes (i.e., making an observation, proposing a hypothesis, designing a research procedure, analysing data, writing a conclusion and communicating a research finding) develop science. These processes are ideally integrated into school science learning (Anderson, 2002). Students are expected to experience the integrated science process skills (ISPS) through several science courses (Adlim, Samingan & Hasibuan, 2014).

Science process skills (SPS), which play an important role in daily life (Aydogdu, 2015), are widely exploited in other disciplines (Rellero, 1998). These skills are generally associated with such terminologies as higher order thinking, critical thinking, formal reasoning (Monica, 2005; Rezba, et al., 1995; Al-Rabaani, 2014).

Many countries (e.g., Indonesia) have adopted National Science Education Standards (NSES) into their science curricula emphasizing inquiry-based learning. Hence, students are expected to acquire and improve their science process skills (Kimble, Yager & Yager, 2006).

Indonesia has revised and released its national curriculum in 2013, also some inquiry laboratory manual (Mahyuna, Adlim & Saminan, 2018) and Science Technology Engineering Mathematic (STEM) laboratory module have been studied (Sari, Adlim & A Gani, 2018).

Even though inquiry has been interpreted in different ways, the “Standard” term means much more thing than a science process. That is, it acts as a vehicle for learning science content (Asay & Orgill, 2010). Given inquiry-based learning and the National Science Education Standards (NRC 2000), inquiry learning process consists of five “essential features”; (a) engaging in scientifically oriented questions; (b) giving a priority to evidence in responding to questions; (c) formulating explanations from evidence; (d) connecting explanations to scientific knowledge; and (e) communicating and justifying explanations (NRC 2000, p. 29). Any teacher may direct various essential features through inquiry-based activities (NRC 2000, p. 29). Asay and Orgill (2010), who reviewed the inquiry studies between 1998 and 2007, reported a need for elaboration on how to reformat the laboratory practical manual and how to link it to the SPS. Yildirim, Calik & Ozmen (2016) stated that inquiry-based learning approach acted as a driving factor in developing SPS.

The objective of science curriculum is to design the relevant learning materials/tools, i.e., textbooks, laboratory practical manuals, handouts, and student worksheets. However, very few inquiry-based laboratory manuals have easily been found in open access literatures (AP®, 2015; Grooms, Enderle, Hutner, Sampson, 2016; Flinn Scientific, n.d). Interestingly, most of them have been prepared in a conventional format (including confirmation experiments).

Integrating SPS into laboratory manual seems to have neglected cognitive-knowledge domains. Unfortunately, many teachers have still not fully understood inquiry-based learning reported by Anderson (2002) and Crawford (1999). For this reason, implementing SPS has been problematic for school science learning and teaching in that they are abstract and need much more efforts for planning science courses (Windschitl, 2004). Therefore, the practical implementation in science classes is likely very low (Monica, 2005; Coil et al, 2010; Sukarno, Permanasari, Hamidah, Widodo, 2013), and it will be more complicated in rural schools (Adlim et al, 2014; Ambross, Meiring & Blignaut, 2014).

Although Miller and Driver (1987) argued that SPS are content-related, separating science learning from SPS results in less meaningful learning and memorizing activities. Also, they are unable to demonstrate SPS and acquire an in-depth content knowledge (Monica, 2005).

SPS can be integrated and implemented onto student worksheets of laboratory practical manuals. Thus, exploring their applicability is a crucial for studying SPS. Assessing pre-service teachers’ capacities is more significant for preparing and educating them to achieve science process skills and scientific processes for the next generation standards.

Taking complex hierarchical features of science process skills into account, two categories appear: basic science process skills (simple skills) and integrated science process skills (complex, higher-order). Basic science process skills (BSPS) are usually experienced in primary school levels, while integrated science process skills (ISPS) can be accomplished by secondary and high school students (Gurses, Çetinkaya, Dogar, & Sahin, 2015; Delen & Kesercioğlu, 2012). BSPS include several skills in observing, comparing, classifying, measuring, experimenting, predicting and inferring (Tobin & Capie, 1982). ISPS contain identifying/controlling variables, stating hypothesis, designing experiments, graphing/interpreting data and stating operational definition (Dillashow & Okey, 1980; Shahali & Halim, 2010).

Science laboratory practical works are expected to train BSPS and ISPS, since science process skills are a part of lab activities. Another BSPS model also uses computer animations and laboratory virtual works (Yang & Heh, 2007; Supriyatman & Sukarno, 2014). Moreover,

using picture books is a successfully method to introduce some science process skills for early childhood education (Monhardt & Monhardt, 2006).

Several studies in SPS have been reviewed. Yildirim et al (2016) reported the profile of SPS implementation in Turkey. Al-Rabaani (2014), who investigated pre-service teachers' SPS (both BSPS and ISPS) levels, reported that their SPS levels of social sciences fell into average level. Further, he implied no significant difference for gender variable at pre-service teachers in Oman. Zedan and Jayosi (2015), who studied with the Palestinian high school students, depicted that female students had higher SPS scores than male ones. Aydogdu (2015), who accessed Turkish science teachers' ISPS, found that they were not at satisfactory level. Karsli, Yaman and Ayas (2010), who sampled Turkish student teachers, addressed that they had difficulty performing SPS-integrated experimental tasks in chemistry laboratories. They also suggested to write SPS-embedded books/worksheets. Similarly, Chabalengula, Mumba and Mbewe (2012) reported that the American pre-teachers' ISPS fell into a moderate level. Downing and Filer (1999) implied that pre-service teachers' science process skills had a positive correlation with their attitudes toward science. Shahali (2015) depicted that Malaysian primary school teachers' understanding of SPS was not as good as their teaching experiences. Although several studies have been reported on the assessment of SPS, how pre-service teachers' ISPS are related to their laboratory practical experiences has been unexplored.

Since the laboratory practical works are conducted by using the conventional science lab manuals then the university usually will face difficulties in improving and accommodating all ISPS. Therefore, worksheets in the laboratory practical manuals need to be analyzed to synchronize pre-service teachers' laboratory work experiences with ISPS. This information will make a great contribution to reformat common science laboratory manuals, student worksheets in laboratory practical manuals and conceptual assignments.

Since ISPS might be drilled during laboratory practical works, then the more students practice the laboratory works, the higher they should have accomplish science process skills. Therefore, this study purposed to explore the ISPS levels of subject-specific pre-service science teachers (chemistry, physics and biology) at different years of the study and compared their levels with those of pre-service math teachers having no science laboratory practices. The current study also intended to explore the content, the frequencies of laboratory practical works, and the students' assignment model and the impact on ISPS.

Research Questions

The following research questions guided the current study:

- Do pre-service teachers' ISPS levels significantly increase along with the proliferation of their lab practical works?
- Do the laboratory practical works significantly affect pre-service science teachers' ISPS levels as compared with those of pre-service mathematics teachers?
- Do pre-service teachers' science syllabuses improve all ISPS?

METHODS

Population and sample

The population of the current study comprised of 813 pre-service teachers enrolled to Semesters III (Admission year was 2015) - V (Admission year was 2014) - VII (Admission year was 2013) in the departments of biology, physics, chemistry and mathematics at Syiah Kuala University, Indonesia. They were distributed to several classes, whose capacities ranged from 24 to 34 students without any academic rank group (homogenous). A total of 360 pre-service teachers (30 x 12); 30 for each semester group (III, V & IV) and for each study

program (biology, chemistry, physics and mathematics) was randomly drawn from each department. The flow chart of the current study is summarized in Figure 1.

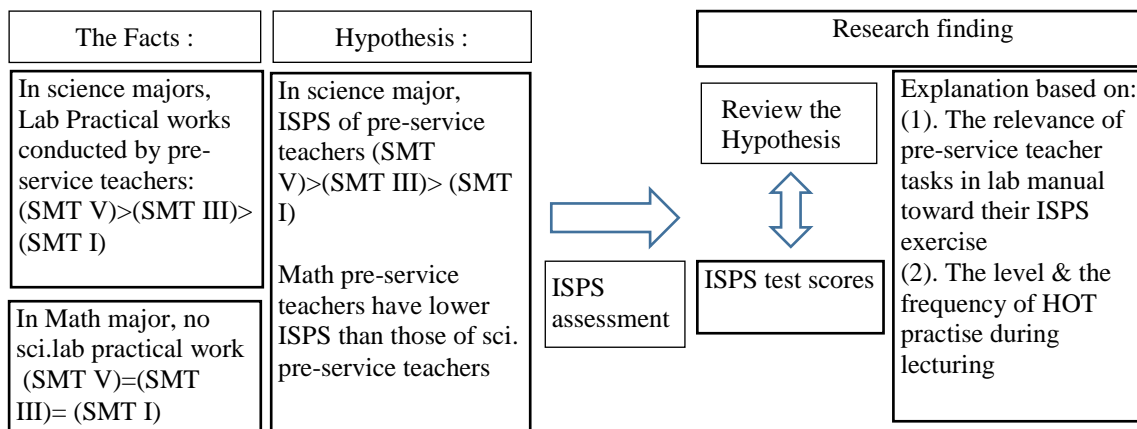


Figure 1. The flow chart of the current study

This study focused on assessing pre-service teachers' ISPS levels and learning experiences. The enrolment test follows national standard with relatively a constant passing grade in each department. The school of education, which has 16 departments, is the oldest institution in Aceh Provinces and one of 374 institutions in Indonesia. Each department runs 4-5 years covering a total of 151 credits, 83% of which are pure science courses. The lecturers dominantly hold master's degree (70-75%), while minority of them has PhD (20%) and Professor (5%) degrees. Their academic backgrounds have highly fallen into mathematics education and pure sciences (biology, chemistry, and physics). A few science educators have been employed in the department. All schools of education in Indonesia follows the same syllabus meeting the national standards. The textbooks and laboratory practical manuals are nearly similar to pure science learning materials for undergraduate programs at worldwide universities (Robson, 2012).

Instrument

A multiple-choice ISPS instrument was adapted from Monica 's (2005) dissertation (see the link at epository.up.ac.za/bitstream/handle/2263/24239/dissertation.pdf;sequence=1) and validated for the current context. In Monica's (2005) study, the items were designed for senior high school students (grades 10-12) and validated with 769 students. Table 1 lists the characteristic of the instrument.

Table 1. The characteristics of ISPS instrument developed by Monica (2005)

characteristics of the instrument	Overall	Acceptable (standard) value
Discrimination index	0.403	≥ 0.3
Index of difficulty	0.402	0.4-0.6
Content validity	0.978	≥ 0.7
Reliability	0.810	≥ 0.7
Readability level	70.29	60-70
Reading grade level	Grade 8	\leq grade 9

The original version of the ISPS instrument, which was in English, was administered to South African senior high school students. Then, the researchers translated it from English into Indonesian language. A group of experts (science and math educators) validated its

translated version with 30 multiple-choice questions. The content validity was found to be 97.7+0.96. The reliability co-efficient measured by a split-half method was found to be 0.96. The researchers did not measure such other parameters as index difficulty was since the instrument was passed to pre-service teachers, whose academic level was higher than senior high school students. The adapted version of the ISPS instrument is outlined in Table 2.

Table 2. An outline of indicators in the ISPS instrument

No.	Indicators	Objectives	Item test number	Total item
1.	Identifying and controlling variables	Describes an investigation, and identifies dependent, independent, control variables	2, 6, 12, 19, 28, 29, 30	7
2.	Operational definition	Describes an investigation, and identifies how variables are operationally defined	1, 7, 22, 23, 26	5
3.	Determining the hypothesis	States a problem with dependent variables and a list of independent variables to identify a testable hypothesis	8, 16, 20	3
4.	Reading graphs and interpreting data	Describes an investigation, obtains results/data, and identifies a graph representing the data	4, 5, 9, 10, 11, 17, 14, 24, 25, 27	10
5.	Designing experiments	Selects a suitable design for test the hypothesis	3, 13, 15, 18, 21	5

Document Analysis and Interview Protocol

The syllabus of each department was analyzed to list the laboratory course works for the laboratory practical manuals. All ISPS was listed and checked to synchronize them with student tasks in the lab practical manuals. The findings were subsequently confirmed by the lab supervisors, lab assistants and several pre-service teachers. Similar procedure was followed for several dominant courses in science and mathematics syllabus to analyze them in regard to the level of Bloom's cognitive taxonomy. Senior science and math lecturers (5 persons) and 10 senior pre-service teachers from each department were interviewed through a structured-interview protocol. That is, senior science and math lecturers listed relevant courses and identified the dominant Bloom levels in their instructions. A similar question list was given to 10 senior pre-service teachers to confirm the lecturers' responses. Finally, their average responses were tabulated.

FINDINGS

Research Question 1: Do pre-service teachers' ISPS levels significantly increase along with the proliferation of their lab practical works?

The year of the study determines the seniority in laboratory practical works. That is, pre-service teacher at the third semester was less senior than those at the seventh semester. The more pre-service students spend time in the campus, they have more experience in the laboratory practical works.

Pre-service teachers must annually accomplish 2-3 lab practical courses. If not, they are dropped out from the university. Pre-service teachers under investigation had a good academic achievement (mean of GPA: 3.0).

Even though five ISPS were distributed into 30 multiple-choice items, 4 of them were deleted due to low discrimination index values. 3 of them were revised because of low validity scores. A total of validated items was 26. However, 20 of them were selected to assess the ISPS, while 6 of them were excluded because of dominant arithmetic calculation. The ISPS items were descriptive, logic and included simple calculation instead of complex one. Mean scores of pre-service science teachers' responses to the ISPS are shown in Table 3.

Table 3. Mean scores and standard deviation values of pre-service science teachers' responses to the ISPS in regard to the year of the study

Semesters	Biology		Physics		Chemistry	
	\bar{x} (%)	SD	\bar{x} (%)	SD	\bar{x} (%)	SD
Semester III	57	15	60	11	59	11
Semester V	61	8	60	11	60	10
Semester VII	66	10	63	14	67	14

As seen in Table 3, mean scores of pre-service science teachers' responses to the ISPS ranged from 57 to 67. These range values were categorized under an intermediate level with a large standard deviation. This finding is consistent with previous studies in Oman, Turkey, and USA (Al-Rabaani, 2014; Karsli et al, 2010 & Chabalengula et al, 2012). That is, because pre-service science teachers' ISPS levels are poor, their capacities of the ISPS may influence their science teaching careers in school and prevent their students' perspectives and science learning motivation in future (Aydogdu, 2015; Shahali, 2015).

Before conducting analysis of variance (ANOVA), normality test was counted using chi-square method at significance $p = 0.05$. This test showed that all was normally distributed with $\chi^2_{\text{calc}} < \chi^2_{\text{table}}$. No significant difference was found for ISPS levels of subject-specific pre-service teachers (biology, physics and chemistry) at similar semester: $F(90, 2) = 0.33$; 0.03 ; 0.80 with, $p = 0.71$; 0.96 ; 0.43 respectively. However, a significant difference between semesters at the given subjects, except for physics. That is, these values for biology were $F(30, 2) = 4.3$, $P = 0.02$; while those for chemistry, $F(30, 2) = 3.6$, $P = 0.03$. There was no significant difference in physics [$F(30, 2) = 0.5$, $p = 0.62$]. It can be deduced that any significant improvement at the ISPS appeared for senior pre-service teachers. This means that experiencing laboratory works is ineffective in evolving all ISPS. However, based on mean scores of pre-service teachers' responses to the ISPS test, dominant fraction of high ISPS scores obviously shifted from less senior (lower semester) to more senior (higher semester) levels for subject-specific pre-service teachers (see Figure 2 a,b,c. For example; the number of pre-service biology teachers' ISPS scores increased along with their lab experience proliferations (Figure 2a). Similar case was observed for pre-service physics teachers (see Figure 2b). That is, their ISPS scores shifted from SMT III (ranging from 26 to 41) to SMT V & VII (ranging from 42 to 73) (Figure 2b). Indeed, the highest ISPS score anomaly appeared at SMT III for pre-service physics teachers. The trend was obviously valid for chemistry education program (see Figure 2c). This finding supports Jerome Bruner's learning theory stating that learners actively experience and construct their own knowledge.

Research Question 2: Do the laboratory practical works significantly affect pre-service science teachers' ISPS levels as compared with those of pre-service mathematics teachers?

As observed in Figure 3, pre-service teachers' ISPS scores were also analyzed to explore weak and strong components at different subjects and the year of the study.

Consistently, the highest mean score of the ISPS was belonging to “graphing and interpreting data,” whilst the lowest one was pertaining to “designing an experiment”. This finding is in a parallel with previous studies reporting that designing an experiment is very difficult for their samples (Monica, 2005; Aydogdu, 2015; Chabalengula et al, 2012).

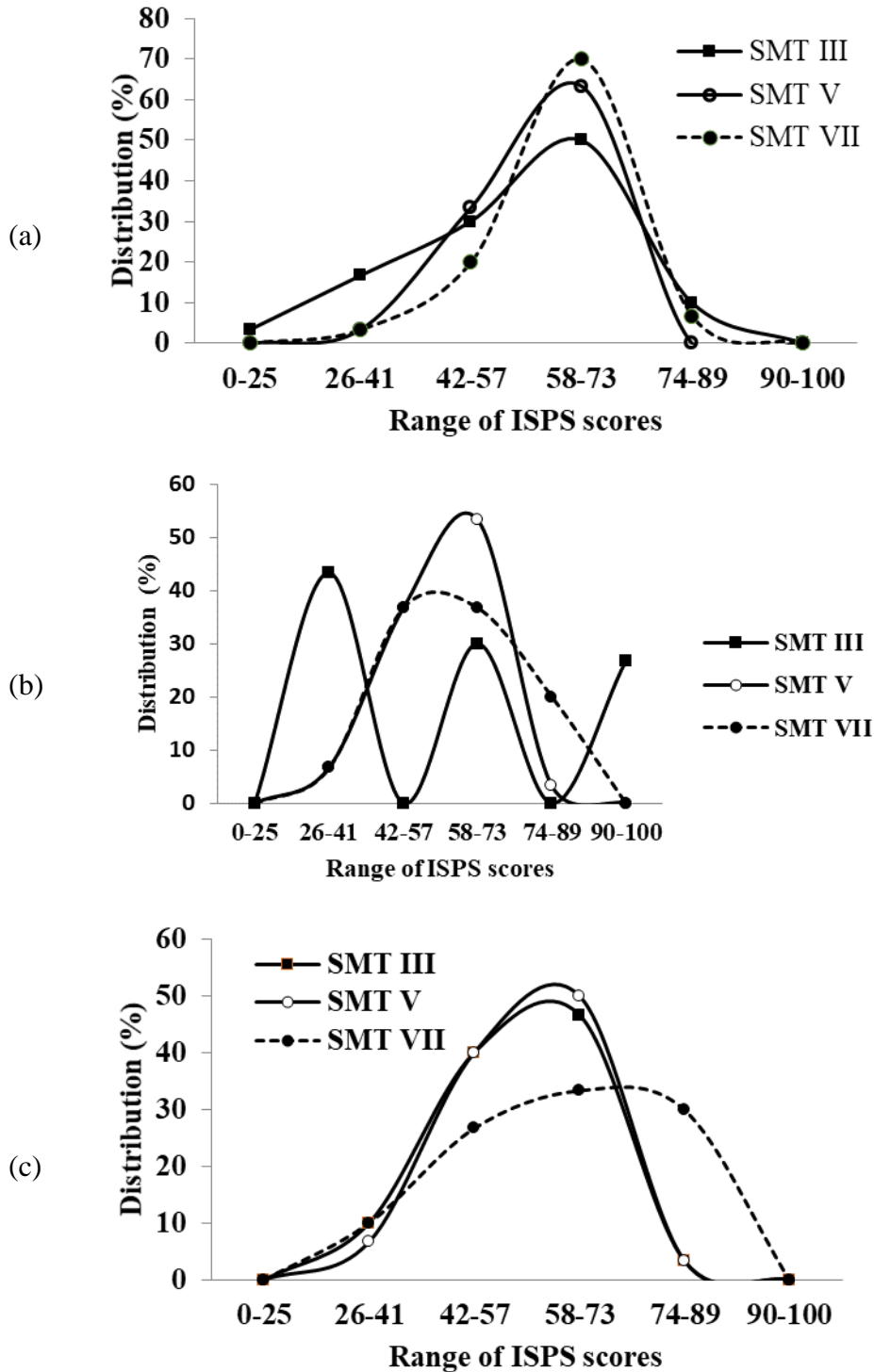


Figure 2. Subject-specific pre-service teacher s’ ISPS scores at different lab practical proliferation (Figure 2a for biology; Figure 2b for physics and Figure 2c for chemistry)

Indeed, the ‘designing an experiment’ skill is a quite complex process incorporating in science process skills, statistical knowledge and systematic thinking skills.

The results indicated that ‘graphing and interpreting data’ skill was the easiest task because it focused on mathematical logic rather than experimental skills. The other ISPS under investigation also required to experience science process skills and higher-order thinking skills.

Lower scores in “Stating Operational Definition”, “Determining the hypothesis” and “Designing an Experiment” skills may result from the present format of the science laboratory practical manuals. That is, since the ISPS under investigation were not found in all lab manuals, pre-service teachers did not experience such skills although taking many laboratory practical works. The pre-service teachers, the head of laboratory and laboratory assistants consistently confirmed this finding.

As seen in Figure 3, pre-service math teachers had higher ISPS scores than pre-service science teachers. This trend appeared at all ISPS and year of the study, except for the ‘Stating Operational Definition’ at Semester III. The ‘designing an experiment’ skill at all semesters was low in all subject-specific pre-service teachers.

The results of ANOVA indicated significant differences between subject-specific pre-service teachers’ ISPS scores at similar semester, except for Semester III. The results of ANOVA for Semesters III, V and VII were $F(120, 3) = 1.9$, $P = 0.13$; $F(120, 3) = 16$, and $F(120, 3) = 9.5$ respectively.

As can be seen from Figure 3, the ISPS is independent on the laboratory practical works since pre-service math teachers, who did not have any laboratory practical work/manual, had the highest ISPS scores. This may come from the features of mathematics activities or learning, i.e., problem solving, reasoning ability and high order thinking skills.

Problem solving activities involve cognitive processes underpinning conceptual and procedural understanding. Conceptual understanding is developed based on interpretation of the facts, whereas the procedural understanding is drilled with exercise skills (Gott & Duggan, 1995).

Higher order thinking (HOT) skills, which are congruent with the ISPS, commonly practice mathematic learning through the ISPS (Tajudin, 2015). Students, who are good at HOT, usually have capacity to manipulate information and idea to synthesize, generalize, explain, formulate hypothesis, or reach some conclusions or interpret a given case. By mastering the systematic thinking skills, they are able to solve problem and discover new meanings or understanding. Some of mathematic assignments requesting to conduct any scientific investigation might also build the ISPS. For example; “*please design a pool, whose area is 24 m^2 , and provide several alternative shapes that allow costumer to choose the options, compare their costs of the surrounding areas*”. To solve this problem, the pre-service teachers need to determine the variables affecting the operational costs and define the hypothesis. Because of designing an experiment or simulation to reject or accept the hypothesis, such a process may have contained and evolved all ISPS.

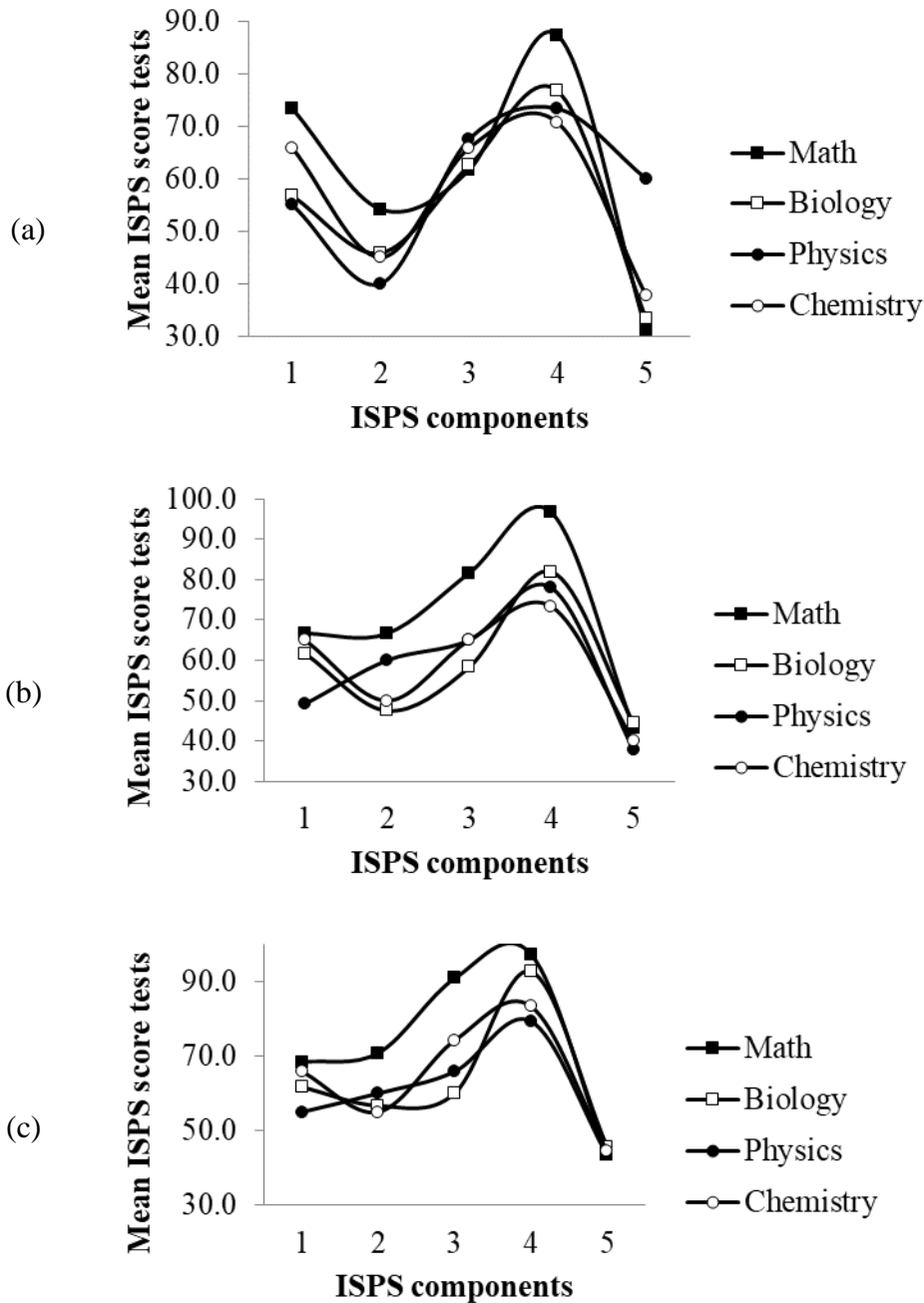


Figure 3. Mean scores of subject-specific pre-service teachers' ISPS ;
(a) Semester III, (b) Semester V, (c) Semester VII;

Coordinate legend:

- (1) *Identifying an controlling variables;* (2) *Stating operational definition*
(3) *Determining the hypothesis;* (4) *Graphing and interpreting data*
(5) *Designing an Experiment*

To compare pre-service science teachers' HOT with those of pre-service mathematics teachers, the researchers conducted structured interview protocols with 5 lectures and 10 senior pre-service teachers, as representatives for each teacher education program. By randomly sampling 10 courses in each teacher education program, the interviewees were asked to check the dominant courses in regard to Bloom's taxonomy. As shown in Figure 4, mathematics courses included their learning activities within C3-C5 of cognitive domain as

compared with science courses. This confirmed that pre-service math teachers had frequently practiced with HOT, which fell into C3-C5 of thinking levels. The logic, reason and systematic thinking may have affected to any improvement in the ISPS scores.

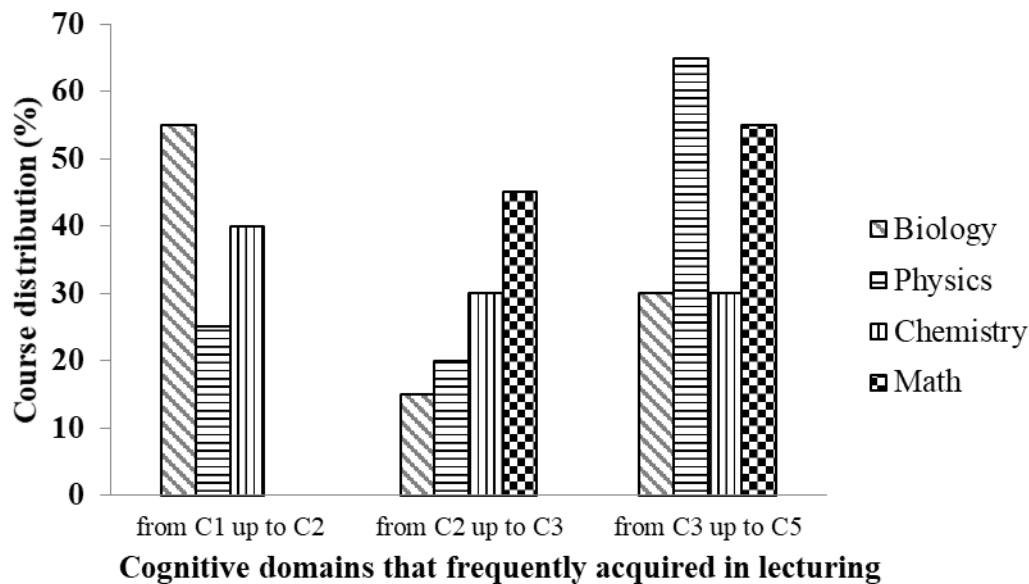


Figure 4. Pre-service teachers' cognitive domains of science and mathematics courses.

Research Question 3: Do pre-service teachers' science syllabuses improve all ISPS?

Even though syllabus has a broad meaning, this study specified science syllabus as the laboratory activities in the laboratory practical manuals. Table 4 presents the number of laboratory practical manuals for each subject in syllabi of teacher training program. The contents of lab manuals were reviewed and matched with the ISPS. It was found that the manual format composed of title of experiment, theory, material and procedure (structured tables for students) and questions.

Three head of laboratories and 15 pre-service teachers as representatives for each subject-specific pre-service teachers were interviewed to verify the ISPS presentation in the manuals. The interview data revealed that the ISPS were not found in the manuals, except for data analysis and graphing (see Table 4).

Table 4. Subject-specific pre-service science teachers' syllabuses

Disciplines	Laboratory Practices (total numbers)		Frequencies of the ISPS explicitly found in the lab manuals				
	Credit hours	Lab. manuals	Identify. & control. variables	Stating operat. definition.	Determining hypothesis	Graphing & interpret. data	Designing experiment
Biology	17	17	none	none	none	always	none
Physics	12	9	none	none	none	always	none
Chemistry	17	13	none	none	none	always	none

The format of the lab practical manuals for each subject was almost similar to those of other well-known universities. Science lab manuals from Durham University, Reed College, Austin College, Massachusetts Institute of Technology and 9 others partially contained the ISPS (Ronson, 2012; "lab reference, n.d" ; 1406manualRRC, n.d & Physics 123, n.d). The

experimental procedures were represented in detail. Also, there was no task for students to state their hypothesis, find the variables and design the experiments (Gobaw, 2016; Tweedy & Hoese, 2005; Basey, Mendelow & Ramos, 2000; Germann, Haskins & Auls, 1996). Biology lab manuals (as a typical format of a lab practical manual) at University of Illinois and University of Maryland, USA contained almost all ISPS (AP® Biology, n.d; Experiment MF, n.d). These manuals, which provided the research questions, asked the students to write their hypothesis, design the experimental procedure, analyze data and write their reports. By doing this, the students may have acquired ‘designing experimental procedures, operational definition and identifying variables’ skills of the ISPS.

DISCUSSION and CONCLUSION

Most of the conventional laboratory practical manuals contained confirmative experimental works, “alike cookbook”. They did not give any chance for students to practice their ISPS, especially “controlling variable” and “designing an experiment” skills. Doing many laboratory practices does not build all ISPS unless the laboratory practical manuals are designed for building the ISPS. The research finding showed that pre-service teachers found difficulty in identifying and controlling variables, stating operational definition, determining a hypothesis and designing an experiment, which are ISPS components. Conventional laboratory manuals may improve “graphing and interpreting data” skill. Doing frequent exercises in problem solving and HOT may evolve the ISPS. Overall, because the conventional laboratory practical manuals had difficulties improving almost all of ISPS, a new format involving in all ISPS need to be developed. Also, this new format should engage students in several assignments containing higher order thinking, problem solving and research questions, tasks and student worksheets.

Suggestions

The participants of this study were undergraduate students which is known as pre-service teachers at a teacher training school. Fur further study, it is interesting to compare their ISPS with the ISPS of in-service teacher and the ISPS of other undergradaute students having major in pure science and engineering. Disparity might be considered because the in-service teachers have more experience in science teaching and the pure scince and engineering students have more science credit hours in their curriculum.

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