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# Effectiveness of Authentic Assessment: Performances, Attitudes, and Prohibitive Factors

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## ABSTRACT

Authentic assessment is an alternative assessment forcing students to perform like a professional in a real work-place. In other words, this type of assessment trains students to be successful-performers in professional jobs. The purpose of this study was to evaluate the effectiveness of authentic assessment based on three elements including students' performance, students' attitudes, and prohibitive factors in authentic assessment implementation. The participants were 37 Indonesian students who studied in a university and enrolled in spectroscopic methods of analysis subject. To achieve the goal of the study, the researchers used a mixed methods design. The data were gained through three techniques including, observation, test, and interview. The findings informed that the learning constructed through the authentic assessment dimensions was effective to facilitate students' performance and foster students' attitudes positively. The prohibitive factors were the difficulty of gaining motivation and enjoyment of the students at the first meeting. The results of this study implied that the authentic assessment was able to scaffold the students to achieve what they need in the future.

**Keywords:** Authentic assessment, student's performances, attitudes, prohibitive factors.

## INTRODUCTION

Unemployment in Indonesia has been high. A total number of unemployed people in August in 2018 reached 14.15 million. The surprising thing was that university graduates contributed 11.65% of the total unemployment (BPS-Statistics Indonesia, 2018). It is partly due to the difficulties that graduates face to reach successful performance in the world of work. In addition, there is a gap between what educators require of students in tasks of assessment and what occurs in the real life or the world of work (Boud, 1990). Therefore,

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Gulikers, Bastiaens, Kirschner, and Kester (2006) revealed that successful performance in this society need to integrate knowledge, skills and attitudes to solve problems that have many possible solutions. Traditional learning, teaching, and assessment are not able to fulfill such requirements.

In a particular, many educators in Indonesia still consider assessment as only "Assessment of Learning (AoL)." In other words, they still use traditional assessment. Traditional assessment tends to assess students based on tests' standardized objective items that have single right answers (Herrington & Herrington, 2006). This perspective views the assessment is a tool to measure the quality of the product conducted by educators (Sabtiawan, 2018). The definition is in line with Angelo and Cross (1993) explaining that assessment is utilized for checking how well students' performance at middle and end of the semester. In other words, the AoL only contributes to inform students about their achievements. With the AoL, students may lack experience in terms of self-assessment. As a consequence, the awareness of what their capabilities are and what the class expects may contravene. Then, the traditional assessment fails to develop students' abilities to perform "real world" task and positive students' attitudes.

There are two perspectives of assessment contributing to bridge the gap, namely, "Assessment for Learning (AfL)" and "Assessment as Learning (AaL)". Experts revealed that through the AfL, educators were able to advise students to improve their learning based on what they chieved (Black & Wiliam, 1998; Heyward & Hedge, 2005; Jones, 2005). Educators can provide feedback to students' works for promoting their learning and informing them regarding how to revise their works at a better level. Arguably, the paradigm of assessment may lead the educators to give positive impacts to the students' learning through the assessment. The argumentation is in line with the finding of researchers explaining the AfL affected positively on the students' performance in higher education (Hidayati, Sabtiawan, & Subekti, 2017; Setiawan & Sabtiawan, 2017). Therefore, educators should consider the implementation of the AfL in terms of the influence of this assessment type on learning.

The AaL is a type of assessment approach viewing the assessment as a foundation for the educators to construct teaching and learning activities. Earl (2012) explained that the AaL occurs when students manage and evaluate their learning, and use the feedback to determine what they have to do. In other words, the AaL can stimulate meaningful learning. The meaningful learning occurs when students are actively engaged in their learning (Mayer, 2010; Novak, 2002). In addition, the students will experience of doing self-assessment. As cited in Leach (2012), self-assessment has been more beneficial than teacher assessment in terms of enhancing learning, preparing students for a democratic society, providing self-control toward their assignments, developing students' metacognitive skills, promoting active learning, forcing thoughtfulness on assignments, increasing students' understanding on assignments, decreasing conflicts between students and teachers, and enhancing students' intellectual and social competencies. Additionally, students can learn through the assessment when the educators implement AaL. As a consequence, the students can work on their assignments based on educators' expectations.

The consideration of the two perspectives of assessment will be an essential aspect for educators for helping their students to achieve successful performances in their future. There is an alternative assessment that can accommodate the two perspectives, namely, authentic assessment. It is an assessment method enabling students to integrate their knowledge, skills and attitudes as professional need in the real world (Gulikers et al., 2006). Cumming and Maxwell (1999) classified authentic assessments as performance, context, complexity, or competence.

According to Rule (2006), there are four characteristics of authentic assessment in higher education, that are (1) involving real-world problems that mimic the work of professionals, (2) including open-ended inquiry, thinking skills, and metacognition, (3) engaging students in discourse and social learning, and (4) empowering students through choice to direct their learning. These characteristics not only help recognize an authentic assessment but also help provide theoretical constructs to describe significant elements or properties of authentic assessment.

Gulikers, Bastiaens, and Kirschner (2004) explained that the authentic assessment has five dimensions to represent its authenticity, which are, tasks, physical context, social context, assessment result or form and criteria. Task means an authentic task that engage students within activities conducted in real life situation as professional practice. Physical context is related to place and time like professional in the real world. Social context is also considered in authentic assessment. In real life beyond the school, professionals work cooperatively in a team. Assessment result or form means authentic assessment assess the product produced by students. In other words, the authentic assessment assesses students' performances. Criteria mean the requirements that should be fulfilled by the students. The criteria of an authentic assessment can also be based on the interpretation of the other four dimensions (Gulikers et al., 2004).

There is educational research that relates to authentic assessment. Herrington and Oliver (1999) conducted a qualitative research study in which they used situated learning and multimedia to investigate higher-order thinking. One element of the situated learning is authentic assessment. The results of the research study showed that the majority of thinking of students in terms of doing tasks was higher order thinking. Moreover, the authentic assessment provides opportunities for deep learning (Gulikers et al., 2006). Therefore, through their dimension, authentic assessment can provide meaningful learning and students can be encouraged to be successful performers as they can relate their learning to the real world situations. The previous research clearly showed that the educators had difficulties to arrange phases of learning and found this approach as time consuming. In this research, an authentic assessment will be modified and applied in learning cooperatively in order to avoid waste of time.

Based on the explanations above, this research evaluates the effectiveness of authentic assessment on students' performances, attitudes, and prohibitive factors during learning. We conducted this research at higher education in spectroscopic methods of analysis subject. This subject has been essential to choose in this research because it was mainly utilized by industry to characterize the composition of matter. Therefore, we hoped students to achieve successful performances in this subject.

***Research Problem:***

The main research problem of this study was "How was the effectiveness of authentic assessment on students' achievement?" The problem is detailed into three questions.

1. What were the students' performances during the implementation of authentic assessment and the factors affecting them?
2. What were the students' attitudes toward learning spectroscopic methods of analysis subject during the implementation of authentic assessment and the factors affecting them?
3. What are the prohibitive factors that appeared during the implementation of authentic assessment?

## METHODS

This study implemented a mixed methods design to examine the research questions. A mixed methods research design is a procedure for collecting, analyzing, and "mixing" both quantitative and qualitative methods in a single study or a series of studies to understand a research problem (Creswell & Plano Clark, 2011). The basic assumption is that the uses of both quantitative and qualitative methods, in combination, provide a better understanding of the research problem and question than either use of the method by itself. The type of mixed method was a triangulation mixed method design (Jick, 1979; Mathison, 1988; Mertens & Hesse-Biber, 2012; Sandelowski, 2000). The design is pictured in Figure 1.

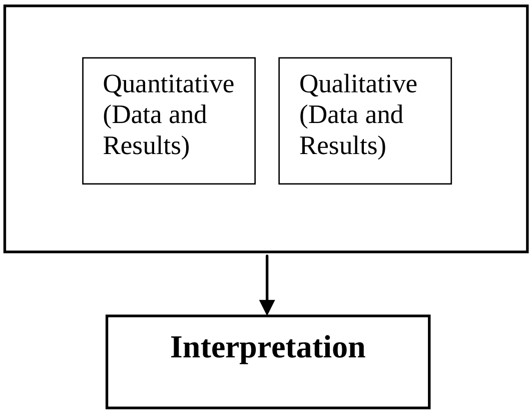


***Figure 1***. The design of triangulation mixed methods

The Figure 1 describes that the quantitative and qualitative data are combined and integrated each other to construct an interpretation.

### a) Participants

The researcher chose one undergraduate chemistry class of Chemistry Department consisting of 37 students, Universitas Negeri Surabaya (Unesa) as research participants. The students were still at the program of spectroscopic methods of analysis subject.

### b) Techniques of Data Collection

This research used several ways to collect the data so that the researchers used both quantitative and qualitative data. The quantitative data were obtained through observation and test while the qualitative data were yielded through observation and interview.

### c) Research Procedures

The implementation was carried out through two procedures, namely, research and teaching procedures. Both procedures were conducted simultaneously. The research procedures contained the implementation of data collection techniques. The research procedures were conducted for six sessions. Observation and research diary were conducted in every session, especially from the first to fourth session. The researchers observed the students' activities by using research diaries (i.e., taking notes). At the fifth session, the researcher collected the quantitative data using a rubric to assess project report and students' presentations. In the last meeting, an achievement test was utilized and researchers conducted the focus group interviews. Interviewees were selected based on the score of students' performance, as explained in the instrument and data collection section. For the teaching procedure, we followed the procedures of cooperative learning involving clarifying and setting goals, presenting information, organizing students in learning teams, assisting group work and study, testing the materials, and providing recognition. In addition, the teaching and learning activities were constructed based on the five dimensions of the authentic assessment, as written in Table 1.

**Table 1.** *Manifestation of authentic assessment dimensions*

| No. | Dimensions of Authentic Assessment | Manifestation |
|---|---|---|
| 1. | Authentic tasks (there are ten elements) | |
| | a. Authentic tasks have real-world relevance. | • The task encourages students to do analysts' jobs in the real work place.<br>• The task encourages students to develop abilities that are needed in the real world, such as writing and oral communication. |
| | b. Authentic tasks are ill-defined. | • The students are only provided simple instruction without detail steps or procedures, such as work sheet. Hence, the students have the opportunity to determine their design or relevant action by themselves. |
| | c. Authentic tasks needs over a sustained period of time. | • The task will be completed within five meetings rather than one meeting only because the task is complex. |
| | d. Authentic tasks provide the opportunity for students to examine the task from different perspectives. | • Students are given the opportunity to search for information from many resources, such as references from books or websites. Thus, they will have various perspectives.<br>• Students are engaged in collaborative activities. |
| | e. Authentic tasks provide the opportunity to collaborate. | • The task needs to be completed in groups.<br>• Students' performances are scored based on team's performance. |
| | f. Authentic tasks provide the opportunity to reflect. | • Encouraging students to perform like an analyst provides opportunities for them to reflect their own experience beyond the school.<br>• The task encourages students in collaborative activities; thus, they can reflect their abilities to the rest of group members. |
| | g. Authentic tasks can be integrated and applied across different subject areas and lead beyond domain-specific outcomes. | • The task encourages students to integrate chemistry knowledge, writing and communication skill. |
| | h. Authentic tasks are integrated with assessment. | • The task will be assessed by using rubrics for project report and oral presentation. |
| | i. Authentic tasks create a holistic product. | • The students do complete action involving analysis a sample, construct the report and communicate the report. |
| | j. Authentic tasks allow competing solutions and diversity of outcome. | • Students are given more opportunities to search for information from many resources, such as references from books or websites rather than only follow the fixed worksheet.<br>• The task allows the diversity of outcomes through project report and oral presentation. |
| 2. | Physical context | • Student learning is conducted in the classroom.<br>• Students will complete the task in the laboratory. |
| 3. | Social context | • Students need to complete the task in team. |
| 4. | Assessment result or form | • Rubric for project report and oral presentation are employed to assess students' performances. |
| 5. | Criteria | • Criteria should be fulfilled by the students based on the other dimensions. |

### d) Techniques of Data Analysis

In this study, we used some analysis techniques adapted from Yin (2017) and Merriam (1988). The first is clustering or categorizing. The clustering or categorizing refers to the grouping together the data that appear similar (Merriam, 1988). In this research, we categorized the data based on the research questions; thus we had three groups of data;

including students' performances, attitudes, and prohibitive factors of authentic assessment implementation. We also took some notes and comments in the margins of research diaries to categorize and make the data more meaningful during the categorization of the data. The second is factoring. The factoring means a process to reduce a large data into focused data. The factoring occurred simultaneously with categorizing in this study. The last is combining qualitative and quantitative data. In this research, the analysis was not only based on the qualitative data that come from observation and interview but also the quantitative data supported the analysis especially related to the students' performances.

## FINDINGS

In the present study, there were three results sections including assessment results of the authentic task (student's performance based on the authentic task), interview results, and research diary results. Each result section is elaborated in more detail in the followings.

### a) Students' Performance

***Assessment Results of the Authentic Task***

Students' performance on the authentic task relates to project reports and oral presentations. The possible highest total score of them is 100. The contribution of the project report was a total score of 60 and the presentation was a total score of 40. Both tasks were assessed using a rubric and the results of these tasks are shown in Table 2.

**Table 2**. *Results of students' performances on authentic task*

| Assessment forms | Aspects of assessment | Score | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **G.1** | **G.2** | **G.3** | **G.4** | **G.5** | **G.6** | **G.7** | **G.8** | **G.9** |
| **Project report** | Purpose | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 3 |
| | Theoretical underpinning | 8 | 5 | 5 | 10 | 3 | 5 | 8 | 8 | 10 |
| | Procedure and Data reporting | 15 | 3 | 8 | 3 | 15 | 3 | 12 | 15 | 15 |
| | Analyzing | 10 | 20 | 15 | 15 | 15 | 10 | 20 | 15 | 20 |
| | Conclusion | 5 | 5 | 5 | 3 | 5 | 5 | 5 | 5 | 3 |
| | Reference | 4 | 4 | 4 | 5 | 5 | 5 | 4 | 5 | 5 |
| | Organization | 5 | 5 | 5 | 4 | 4 | 5 | 4 | 5 | 5 |
| **Oral presentation** | Subject knowledge | 15 | 15 | 15 | 20 | 15 | 15 | 10 | 10 | 15 |
| | Visual | 5 | 4 | 5 | 5 | 4 | 4 | 4 | 4 | 5 |
| | Eye contact | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 5 |
| | Team work | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 5 | 4 |
| **Total Score** | | **82** | **76** | **76** | **79** | **79** | **65** | **80** | **80** | **90** |
| **Alphabetical Score** | | **A-** | **B+** | **B+** | **B+** | **B+** | **B-** | **A-** | **A-** | **A** |
| **Explanation** | | **Pass** | **Pass** | **Pass** | **Pass** | **Pass** | **Pass** | **Pass** | **Pass** | **Pass** |

By transforming the scores of the groups into alphabetical grades that the university possesses (See Table 2), the sixth group (G.6) received a grade of B-; the second (G.2), third (G.3), fourth (G.4), and fifth group (G.5) received a grade of B+; the first (G.1), seventh (G.7), and eighth (G.8) received a grade of A- whereas the ninth group (G.9) received a grade of A. This result represents that all students passed the subject for the particular topic. The percentage distribution of the alphabetical grades are presented in Figure 2.

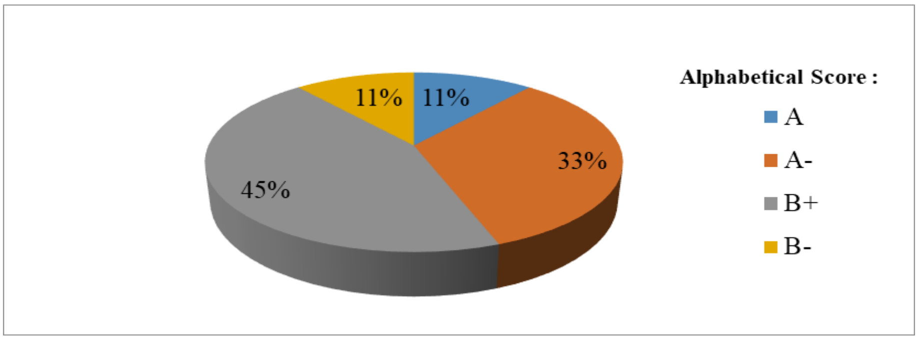


***Figure 2***. Diagram of achieved alphabetical score in percentage form

As seen in Figure 2, no group received a grade of B, C+, C, D, and E. Thus, it was considered that the four groups of students had good concept of atomic absorption spectroscopy and skills.

***Interview Result Concerning Student's Performance***

The purpose of the interview results was to support the discussion about students' performance. The interviewees included students with low level performance, students with middle level performance, and students with high level performance. Table 3 presents the interview results regarding students' performance.

**Table 3**. *Interview Result Concerning Student's Performance*

| Questions | Interviewees | | |
|---|---|---|---|
| | **Students with low level performance** | **Students with middle level performance** | **Students with high level performance** |
| What is your opinion about the effect of authentic assessment implementation on your performance? | *... we got explanation theory at the first and then implemented it through the project... this way affected our performance positively and mastery of the topic was deeper.* | *… it is very useful for our performance improvement because the theory and project were discussed and prepared well before…* | *... Our performance in term of constructing project report and doing presentation were increasing positively because there was a discussion…* |

Based on the results of the interview, as seen in Table 3, it can be summarized that the students felt their performances were affected positively. They felt their concept mastery and their performance on authentic task got positive impacts through the learning process.

***Research Diary Result Concerning Students' Performance***

The purpose of research diary results was to support the discussion about students' performance. Table 4 informs the results of the research diary regarding students' performance.

**Table 4**. *Research diary result concerning student's performance*

| No. | Date | Notes |
|---|---|---|
| 1. | September 20th, 2013 | • "After the students had been forced, the learning ran quite well and all groups were starting to contribute in the discussion. In the other side, the four groups followed the learning dominantly. (P4) |
| 2. | October 2nd, 2013 | • "They presented the design and they discussed each other. During the discussion, they seemed to start enjoying their learning because they shared information to each other without reluctance." (P8)<br>• "I enhanced the students to discuss the theoretical aspects, and then some groups gave rise discussion related to the theoretical aspects. It is essentially needed to |

| No. | Date | Notes |
|---|---|---|
| | | cover their mastery about the concept of atomic absorption spectroscopy.” (P9) |
| 4. | October 25th, 2013 | • “Each group presented their draft and they discussed each other. During the discussion, they seemed to start enjoying their learning because they shared information to each other without reluctance.” (P17) |
| 5. | November 6th, 2013 | • “Each group presented their final report and they discussed each other. During the discussion, they seemed to start enjoying their learning because they shared information to each other without reluctance.” (P21)<br>• “All groups were active during the learning through presentations.” (P22) |

According to phenomena (P) in Table 4, it can be said that the students became successful as active learners. The students shared information with each other through presentations. In addition, they contributed ideas and posed questions during learning.

### b) Students’ Attitudes

To examine the students’ attitudes, we used three research results including results of research diary, interview, and affective ability observation. Each result section is elaborated in more detail in the followings.

***Research Diary Results Concerning Students’ attitudes***

The purpose of the research diary results was to support the discussion about students’ attitudes. As indicated in Table 5, the students showed positive response to the learning (authentic assessment with embedded cooperative learning). They got their enjoyment and interest during the learning, as stated in the quotes P5, P8, P10, P14, P17, P19, P21, and P23.

**Table 5**. *Research diary result concerning student’s attitudes*

| No. | Date | Notes |
|---|---|---|
| 1. | September 20th, 2013 | • ”The class also showed good respond when I explained the task. They asked some questions related to the task, seemed had good motivation, and interested enough.” (P5) |
| 2. | October 2nd, 2013 | • “They presented the design and they discussed each other. During the discussion, they seemed to start enjoying their learning because they shared information to each other without reluctance.” (P8)<br>• “In this meeting the students started to pose questions and ideas without forcing. On the other hand, there were some groups still seemed not confidence to pose questions and ideas” (P10) |
| 3. | October 18th, 2013 | • “The learning condition in the laboratory tended to noisy but they seemed to enjoy their practicum.” (P14) |
| 4. | October 25th, 2013 | • “Each group presented their draft and they discussed each other. During the discussion, they seemed to start enjoying their learning because they shared information to each other without reluctance.” (P17)<br>• “In this meeting the students posed questions and ideas without forcing.” (P19) |
| 5. | November 6th, 2013 | • “Each group presented their final reports and they discussed each other. During the discussion, they seemed to start enjoying their learning because they shared information to each other without reluctance.” (P21)<br>• “In this meeting the students posed questions and ideas without forcing.” (P23) |

***Interview Result Concerning Students’ Attitudes***

The purpose of the interview results was to support the discussion about students’ attitudes. The interviewees involved low, middle, and high level performance students.

**Table 6**. *Interview result concerning student's attitudes*

| No. | Questions | Interviewees: Students with low level performance | Students with middle level performance | Students with high level performance |
|---|---|---|---|---|
| 1. | How about your motivation during this learning? | *We got motivation to follow the learning because we learned like an analyst… Discussion and presentation were able to motivate…* | *We were motivated to learn this topic because of this learning way I got* | *… the discussion showed our weaknesses so that we were enhanced or forced to refine it…* |
| 2. | What is your interesting toward this topic after the implementation of authentic assessment? | *… we learned this topic through discussion… We learned like an analyst so that it was appropriate with our future* | *We were interested in it because if there was a problem or discussion, we discussed and synchronized it with several aspects (theory and practice).* | *We felt interested in this topic because by using this method we were not boring to listen to the lecturing dominantly but we were hoped to be active in this learning* |
| 3. | What is your enjoyment during this learning? | *We got the enjoyment during learning… there was synchronized between theory and practice so that it was unforgettable.* | *Initially we were uncomfortable… it was different from our habit. Then, I felt enjoy because we learned in a team.* | *… I could share information with my friends in a group and other groups without reluctance.* |

Table 6 shows the result in more details. Based on the interview results, it can be said that students got enjoyment and interest during the learning although they felt uncomfortable at the first moments. They argued that their learning way was able to promote their enjoyment and interest.

### *Results of Affective Abilities Observation*

Affective abilities relate to the students' behaviors during learning. In this research, the affective abilities were only focused on working collaboratively, posing ideas, and posing questions.

**Table 7**. *Results of observation of affective abilities*

| Student group | Score of achievement: 1st meeting | | 2nd meeting | | 3rd meeting | 4th meeting | | 5th meeting |
|---|---|---|---|---|---|---|---|---|
| | Posing idea | Posing question | Posing idea | Posing question | Work collaboratively | Posing idea | Posing question | Posing question |
| G.1 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 |
| G.2 | 2 | 2 | 2 | 4 | 4 | 4 | 3 | 4 |
| G.3 | 4 | 2 | 3 | 3 | 4 | 3 | 3 | 4 |
| G.4 | 2 | 2 | 2 | 2 | 3 | 4 | 4 | 3 |
| G.5 | 3 | 2 | 2 | 3 | 4 | 4 | 4 | 3 |
| G.6 | 3 | 2 | 3 | 2 | 3 | 3 | 3 | 3 |
| G.7 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 |
| G.8 | 4 | 3 | 3 | 3 | 4 | 4 | 4 | 3 |
| G.9 | 4 | 2 | 4 | 3 | 4 | 4 | 4 | 4 |
| **Total score** | 27 | 20 | 24 | 27 | 33 | 33 | 32 | 31 |
| **Number of group** | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |
| **Average score** | 3.00 | 2.22 | 2.67 | 3.00 | 3.67 | 3.67 | 3.56 | 3.44 |
| **Achieve Ment level** | **Good** | **Need improve ment** | **Need improve ment** | **Good** | **Excellent** | **Excellent** | **Excellent** | **Good** |

(**Criteria:** 1.00 – 1.99 = Unacceptable; 2.00 – 2.99 = Need improvement; 3.00 – 3.49 = Good; 3.50 – 4.00 = Excellent)

Table 7 informs that the achievement level of posing question decreased (from excellent to good level) during observation of meeting 4 (presentation of project report draft) and 5 (presentation of final project report). It was because the concepts and their difficulties dominantly were discussed in the meeting 4. Hence, the side effect was the decreasing number of students' questions in the meeting 5. This effect cannot be said a negative effect for students' learning because the students were prepared well in the meeting 4 so that it was assumed that they understood the concept and solved their difficulties dominantly in the meeting 4. Therefore, they were more confident into the actual presentations in the meeting 5.

### c) Prohibitive Factors

To evaluate the prohibitive factors, we also used three research results, which are, research diary results, interview results, and observation results of lesson plan implementation.

***Research Diary Results Concerning Prohibitive Factors***

The purpose of the research diary results was to support the discussion about prohibitive factors. Table 8 informs the result as follows.

**Table 8**. *Research diary results concerning prohibitive factors*

| No. | Date | Notes |
|---|---|---|
| 1. | September 20th, 2013 | • "All students attended the class. When I entered the class, the students seemed nervous or even confuse because they talked to each other about that day lecturing. Probably, they thought what and how they will learn." (P1)<br>• "On the other hand, I needed to force them (almost all groups) in terms of asking questions and posing ideas. There were only four groups (group 1, 3, 8, and 9) that posed question and idea without my forcing." (P3) |

Table 8 informs that the students seemed nervous and stress at the first moments. In other words, active learning was still not usual yet at the beginning so that the students did not get their enjoyment yet at the first moments as stated in the quotes P1 and P3.

***Interview Results Concerning Prohibitive Factors***

The purpose of interview results was to support the discussion about the prohibitive factors. The interviewees involved low, middle, and high level performance students.

**Table 9**. *Interview result concerning prohibitive factors*

| No. | Questions | Interviewees | | |
|---|---|---|---|---|
| | | **Students with low level performance** | **Students with middle level performance** | **Students with high level performance** |
| 1. | Please, give me your explanation about the implementation of this method during the lesson! | *The implementation of this method during the lesson was good… I hope the meeting is tighter in a week (twice in a week) but it will need to adjust the schedule.* | *The implementation of the project in the laboratory should be arranged in a better way. The condition was too crowded.* | *… I suggest that in order to give the initial information about AAS, the video about an analyst using AAS is needed to present at the first moment (not only picture).* |

| No. | Questions | Interviewees | | |
|---|---|---|---|---|
| | | **Students with low level performance** | **Students with middle level performance** | **Students with high level performance** |
| 2. | How is your perception if this method is implemented in the future at the same topic? | *... it can be better to implement in the future. It needs to adjust the schedule…* | *It can be implemented even for other topics…* | *It is possible to do because this method is able to force the students as active learner…* |

As seen in Table 9, the students indicated that the meetings needed to be adjusted in tighter (twice in a week), the condition of laboratory during doing projects was too crowded so that it should have been arranged in a better way, video about AAS should have been provided at the first moment, and the method of learning was possible to implement in the future at the same topic.

### *Observation Results of Lesson Plan Implementation*

This observation focused on how far the lesson plan was successfully and completely done in class. In other words, the result of this observation was as a mirror the quantity and the quality of the lesson plan implementation. Table 10 informs that scenarios in each phase were implemented in excellent and good levels.

**Table 10**. *Observation results of lesson plan ımplementation*

| Phase of the learning | Assessed Aspects | Score | | Average Score | Level/ Category |
|---|---|---|---|---|---|
| | | **Observer 1** | **Observer 2** | | |
| Phase 1: Clarify goals and establish set. | Motivating students and asking prior knowledge of students | 3 | 3 | 3 | Good |
| | Motivating students to pose idea | 4 | 4 | 4 | Excellent |
| | Giving information of learning objectives | 4 | 4 | 4 | Excellent |
| Phase 2: Present information. | Presenting basic knowledge briefly | 3 | 4 | 3.5 | Excellent |
| | Guiding students to pose idea and questions | 4 | 4 | 4 | Excellent |
| | Communicating authentic assessment | 4 | 4 | 4 | Excellent |
| Phase 3: Organize students into learning teams. | Organizing students in group | 3 | 4 | 3.5 | Excellent |
| | Communicating authentic task | 3 | 3 | 3 | Good |
| | Providing some example of analysis using AAS | 4 | 4 | 4 | Excellent |
| | Determining the project | 4 | 4 | 4 | Excellent |
| | Providing opportunity to the students for designing their experiment | 3 | 4 | 3.5 | Excellent |
| Phase 4: Assists teamwork and study. | Asking each group to present their design of project | 4 | 3 | 3.5 | Excellent |
| | Motivating students to pose idea and questions | 3 | 3 | 3 | Good |
| | Giving feedback to each group | 4 | 4 | 4 | Excellent |
| | Conducting the project | 4 | 4 | 4 | Excellent |
| | Announcing to the students about laboratory safety | 3 | 3 | 3 | Good |
| | Giving opportunity the students to conduct their project | 3 | 4 | 3.5 | Excellent |
| | Asking the students to record the result | 3 | 3 | 3 | Good |
| | Having the students to present their draft of project report | 4 | 4 | 4 | Excellent |

| Phase of the learning | Assessed Aspects | Score | | Average Score | Level/ Category |
|---|---|---|---|---|---|
| | | Observer 1 | Observer 2 | | |
| | Motivating students to pose idea and questions | 3 | 4 | 3.5 | Excellent |
| | Posing questions to each group | 3 | 3 | 3 | Good |
| | Giving feedback to each draft | 4 | 4 | 4 | Excellent |
| Phase 5: Tests on the materials. | Asking the students to present their final project report | 4 | 4 | 4 | Excellent |
| | Motivating students to pose questions | 4 | 3 | 3.5 | Excellent |
| | Posing questions to each group | 4 | 4 | 4 | Excellent |
| | Giving feedback | 3 | 4 | 3.5 | Excellent |
| Phase 6: Provide recognition. | Guiding the students to summarize | 4 | 3 | 3.5 | Excellent |
| | Providing group reward | 4 | 4 | 4 | Excellent |

(**Criteria:** 1.00 – 1.99 = Unacceptable; 2.00 – 2.99 = Need improvement; 3.00 – 3.49 = Good; 3.50 – 4.00 = Excellent (based on Arikunto (2011))

It seemed that the lesson plan was successful to bring the authentic assessment with embedded cooperative learning to class. However, there were aspects still needed to be concerned for further implementation of the lesson plan such as motivating students. These aspects may have impacted students' learning. Further discussion will be brought in Discussion Section.

Knowing that six phases of the lesson plan consisted of 28 steps of assigning teaching and learning packed as scenarios, the implementation of that was 100% because all steps were implemented. Such percentage was calculated by dividing the number of implemented aspects over the total number of observed aspects and then multiplied by 100%.

## DISCUSSION and CONCLUSION

### a) Students' Performance

In the authentic task, the students did the task adjusted to the real work place. They conducted a project. To represent the result of the project, the students needed to construct a project report and then communicated it with each other. Thus, there were two assessed categories (i.e., project report and oral presentation). In order to overcome subjectivity in the assessment, each category was assessed by using a rubric. All groups gained scores above the minimum requirement to pass the subject matter (based on Unesa standard score). There were three groups that received excellent scores. It can be said that this learning affected the students' performance positively. In other words, the authentic assessment facilitated the students' performance. Students' statements in the interview supported this results.

"… this way affected our performance positively…" (low performance student)

"… it was very useful for our performance improvement…" (middle performance student)

"… Our performance in term of constructing project report and doing presentation were increasing positively…" (high performance student)

This fact can be explained using several reasons. Each reason is discussed in details below.

Firstly, the students were always provided with opportunities to discuss each other. The discussion was promoted through one of the authentic assessment dimensions, that is, social context. Through the discussion that was noted in the research diary, the students got useful suggestions to improve their work. This reason is also in the same line with the students' perspectives below.

"Through discussion, we got corrections or inputs that were very useful…" (low performance student)

"… Our performance in term of constructing project report and doing presentation were increasing positively because there was discussion… the discussion showed our weaknesses…" (high performance student)

In other words, the students received some feedbacks. There were many reviews stated that feedback was needed by students during their learning. As cited Woolfolk (2008), feedback emphasizing progress is the most effective because when the feedback highlighted accomplishment, the participants' self-confidence, analytic thinking, and performance were all enhanced. The flow of discussion during learning was student-student-lecturer-student. This occurred because we wanted the students to do corrections through themselves and their friends. Posing ideas and questions from students were at the good and excellent levels. Thus, they did not only get immediate feedback but also delayed feedback. Schooler and Anderson (1990) found that delayed feedback is more beneficial to detect self-errors at which it may benefit to students becoming independent learners and being able to learn as self-concept explorer.

Secondly, the students received a good preparation. Based on the guideline, the groups presented their design (meeting 2) before doing the project (meeting 3), presented their draft (meeting 4) before submitting and presenting the final report (meeting 5). The good preparation was also happening because of the third characteristic of the authentic task, that is, investigation of authentic tasks in a sustained period of time. The students were also provided two rubrics and clearly informed about the meaning of each assessment item. The result of the interview below also supports this perspective.

"… the theory and project were discussed and prepared well before…". (middle performance student)

Therefore, the students needed a good preparation for their reports and presentations. It is because they liked to before actual implementation.

Thirdly, the students collaboratively worked in the groups. The collaborative working occurred one of the authentic assessment dimensions, that is, social context. In this part, the students' performance was measured by using the authentic task so that the collaborative working was useful for doing well the task. It is because there were some perspectives toward the task that could be used to finish the task well. Joyce and Weil (1992) revealed that the shared responsibility and interaction produce a more positive feeling toward a task. It means that the students in each group had a positive feeling toward the task. Therefore, by using the collaborative working, the students could perform well on the task.

### b) Student's Attitudes

This part is constructed to examine the student's attitudes toward learning the topic during the implementation of authentic assessment. We used three sources including students' perspectives through the result of the interview, research perspective through the results of the research diary, and the result of affective abilities observation. We combined the three types of data to support each other and construct a comprehensive discussion as provided below. This discussion of students' attitudes only focused on interest and enjoyment. The analysis and discussion of both focuses are elaborated in the following paragraphs.

#### *Analysis of Students' Interests toward Learning the Topic after the Implementation of the Authentic Assessment*

The interest is an attitude that is needed by everyone in term of doing something well, especially for students who learn the material or topic. It is because greater interest tends to create more positive emotional responses to the material, then greater persistence, deeper processing, better remembering of the material, and higher achievement (Ainley et al., 2002; Pintrich, 2003; Schraw & Lehman, 2001). Moreover, greater interest, more attention toward science. As cited in Fajardo, Bacarrissas, and Castro (2019), more attention can lead students to acquire positive attitudes towards science. On the other hand, each student does not have the same level of individual interest toward the material or topic so that it is needed to promote situational interest for students. Boekaerts and Minnaert (2006) asserted that situational interest is generated in the situation itself with certain conditions or stimuli. Therefore, we discussed how the interest of the students toward atomic absorption spectroscopy topic below.

There were several indications that the students were interested in the learning. Some research diary notes as the indications of the students' interests at the phenomenon 5, 10, 19, and 23 are shown below.

> ”The class also showed good respond when I explained the task. They asked some questions related to the task, seemed had good motivation, and interested enough.” (P5)
>
> “…. pose questions and ideas without forcing.” (P10, P19, P23)
>
> In addition, these findings are completed by the result of affective abilities observation that presented in Table 6.

The data informed that posing questions and ideas (meeting 3-5) were in the range of good and excellent level. Through enthusiastic posing questions and ideas, the students wanted to show that they were enthusiast to get information about the topic further. It means that the students were interested in the topic by showing their good responses. Moreover, to strengthen the above indications, the result of the interview below informed that students were interested during the learning.

> “It was interesting…” (low performance student)
>
> “We were interested to it…” (middle performance student)
>
> “We felt interest in this topic…” (high performance student)

The result of the interview indicated that the three levels of students' performance also stated their reasons differently why they were interested.

There were three reasons for students' interest appeared in the result of the interview. Firstly, the students were interested because they were facilitated to learn the theory through practice as stated by a middle performance student below.

> “…we discussed and synchronized it with several aspects (theory and practice).” (middle performance student)

In this learning, the authentic task, the first dimension of authentic assessment, forced the students to practice directly in the laboratory like a professional, but the students were also forced to mastery the theory or concepts to finish the tasks well. Therefore, the students' interest level was raised through the authentic task.

Secondly, the students' interest was promoted because they were given opportunities to discuss each other intensively as stated by a high performance student below.

> ”… we were not boring to listen to the lecturing dominantly but we were hoped to active in this learning…” (high performance student)

The high performance student rose the statement because of the existence of social context (one of authentic assessment dimension) and the third authentic task characteristic (authentic tasks needs over a sustained period of time (Herrington et al., 2010). Through more intense discussions, the students can get opportunities to find more information about the topic and they can be more active to speak about the topic. Hence, this process could increase the possibilities that the students found their interests in the topic.

Thirdly, their interests were increased with their engagements to the activities like the real work place as stated by a low performance student below.

"… We learned like an analyst so that it was appropriate with our future…" (low performance student)

The students' reasons for their interest rose because the authentic task was provided for the concept learning. Gulikers et al. (2004) proposed that the authentic task engages students within activities conducted in real life situations as professional practice. Thus, it is not surprising when students said "it was appropriate with our future" because students were aware that they were learning the job as they wanted. In addition, Aladejana and Aderibigbe (2007) explained that laboratory work (real work of analyst) conducted in a good environment can promote student curiosity. Therefore, the students' interest can be increased.

Based on the discussions above, the students were interested the atomic absorption spectroscopy topic after getting the stimuli. Of course, the stimuli were the learning constructed by using authentic assessment dimensions. In other words, the situational interest was promoted after the implementation of the authentic assessment.

***Analysis of Students' Enjoyment during Learning the Topic***

Besides the students' interest, students' enjoyment is also needed to give positive feeling toward the learning. Through the positive feeling, the students can learn the topic and do the task well without trouble. As a consequence, they can achieve the desired level of performance as high as possible.

The indications of students' enjoyment can be seen in the results of the research diary noted at the phenomenon 8, 14, 17, and 21. Also, the results of the interview strengthen those phenomena as stated below.

"We got the enjoyment during learning…" (low performance student)

"… Then, I felt enjoy…" (middle performance student)

"I enjoyed this learning …" (high performance student)

Thus, the research diary's note and the students' perspective toward their learning agree that the students enjoyed the learning while the authentic assessment was implemented.

There were three different reasons standing beyond the student's perspective in term of their enjoyment. First, the reason comes from a high performance student as revealed below.

"… I could share information with my friends in a group and other groups without reluctance." (high performance student)

The statement above informs that students' experience in discussion with others can promote their enjoyment. According to them, the difference was that they had more opportunities to share their known or unknown each other without reluctance. Their enjoyment during the discussion was also noted in the research diary as below.

"They presented the design and they discussed each other. During discussion, they seemed to start enjoying their learning because they shared information to each other without reluctance." (P8)

"Each group presented their draft and final report, and they discussed each other. During discussion, they seemed to start enjoying their learning because they shared information to each other without reluctance." (P17, P21)

Students had more opportunity to discuss each other because of the implementation of learning guideline constructed by using the authentic dimensions. Based on the P8, P17, and P21, it can be seen that the students learned the topic through discussion dominantly. Therefore, it can be said that the way of learning fostered the students' enjoyment.

Second, the enjoyment of student arguably was arisen because they were not forced to master the concept in a short time. This perspective describes the success of an authentic task characteristic proposed by Herrington et al. (2010). It is that authentic tasks needs over a sustained period of time. Besides the opportunities for discussions, they were not forced all of the concepts. In addition, it could be seen from the guideline that the students were provided five meetings to discuss the concept of the topic. Hence, the students were able to learn the topic with their enjoyment and without burden or forcing their capabilities. As a consequence, they could process the concept of the topic to long-term memory. As explained by Woolfolk (2008), access to information in long-term memory requires time and effort.

Third, the perspective rose from the low performance students as stated below.

"… there was synchronized between theory and practice so that it was unforgettable." (low performance student)

It can be seen from the lesson plan that the students learn the theory of atomic absorption spectroscopy (AAS) through learning how to analyze trace metals by using AAS in the real situation. The students did not need to learn the theory and practice separately. Hence, it can be argued that the students felt enjoy because they could synchronize between the theory and practice easily without separating them. In addition, this pin point also relates to the laboratory activity. As noted in the research diary below that the activity can enjoy student.

"The learning condition in the laboratory tended to noisy but they seemed enjoy their practicum." (P14)

Likewise, Hofstein and Lunetta (2003) argued that students' attitudes move towards positive states when teachers use laboratory activities to enhance teaching. Therefore, based on this third perspective, the authentic task as one of the authentic assessment dimensions facilitated the enjoyment of student during learning of AAS topic. As cited in Areepattamannil (2012), such a case is influenced by the use of hands-on activities at which students enjoy integrating their cognitive abilities with senses and motions.

Fourth, the middle performance students purposed that they got the enjoyment because they learned in a group as stated below.

"… I felt enjoy because we learned in a team." (middle performance students)

Their perspective is in line with a statement as cited in McInerney and McInerney (2010) stating that the social interaction within groups can promote good behavior among teammates. In other words, interaction and supporting each other between teammates will strengthen the relationship between them. Especially, growing good relationship between less and more capable students is one of the important purposes of learning in a team. Hence, if a good relationship is a success to form between them, the enjoyment of learning in a group can happen.

In summary, the students' attitudes involving interest and enjoyment were promoted toward the learning of AAS topic. By reconsidering the discussion above based on the students' perspectives, research diary, and result of affective abilities observation, the learning environment can be considered as the main factor for the student's interest and enjoyment. As proposed by Fraser (2001), the learning environment has a tremendous power to affect the students' achievements; thus the effectiveness of learning can be created by the appropriate learning environment. Therefore, authentic assessment with embedded cooperative learning can create the appropriate learning environment for the students who learn AAS topic.

**c) Prohibitive Factors**

Although the implementation of the lesson plan was 100% based on the results of observation, we also found several obstacles during the learning. In this section, hence, we discuss the obstacles or prohibitive factors that can disturb the learning. To get discussion comprehensively, we used three sources of data including the research diary, results of the interview, and observation result of the lesson plan implementation. By using those data sources, we discuss the prohibitive factors below.

The first obstacle was that we got difficulties in promoting students' enjoyment at the initial moments. At the first meeting, the students seemed stressed when they were placed at the center of their learning. In other words, arguably they did not usually learn as active learners. It can be seen in the phenomena 1 and 3 of the research diary below.

> "All students attended the class. When I entered to the class, the students seemed nervous or even confuse because they talked to each other about that day lecturing. Probably, they thought what and how they will learn." (P1)

> "… I needed to force them (almost all groups) in terms of asking questions and posing idea. There were only four groups (group 1, 3, 8, and 9) that posed question and idea without my forcing." (P3)

The results of the interview also support the finding noted in the research diary as stated below.

> "Initially we were uncomfortable… it was different from our habit..." (middle performance student)

For that quote, it is actually in line with an explanation as cited in Woolfolk, et. al (2008) state; students mind that the learning does not merely encompass balanced, synchronized, and rhythmical processes. The learning also involves a huge amount of chaos and conflict that can make students feel stressful and confused. Hence, students need to adapt in order to rebalance their minds (McInerney & McInerney, 2010) towards the new learning model or situation. Based on this obstacle, it is purposed that the students' confusion and stress at the first moment could be eliminated by more optimizing the phase 1 of cooperative learning guideline.

The second obstacle we had was the difficulty to motivate the students to pose questions and ideas at the initial moments. This was also because the students did not usually learn as active learners. Motivating students need to be concerned for the further implementation of the lesson plan. McInerney & McInerney (2010) revealed that motivation is an internal condition that keeps students at tasks. Arguably, this obstacle can be minimized by providing more information about the role of this topic for their future, such as showing videos about AAS that students suggested to increase their motivation. It is stated as follows.

> "… the video about an analyst using AAS was needed to present at the first moment (not only picture)." (high performance student)

Furthermore, if motivating students was successful, the obstacle 1 can be minimized.

The third obstacle is stated by the students through the result of the interview below.

> "…The condition of instrument laboratory was too crowded." (middle performance student)

This condition occurred because the instrument of AAS was limited. On the other hand, this obstacle can be still avoided by rearrangement the injection sample time in a better way.

## Suggestions

To increase the implementation quality of authentic assessment with embedded cooperative learning guideline that can be optimizing the impact of the treatment on the students' performance, the obstacles should be further reconsidered. According to Gardner and Belland (2012), through several educational research, they suggested that in promoting students' active learning, like the authentic assessment with embedded cooperative learning guideline, it has to be supported by many efforts and puts many trials to get success in fulfilling students' needs in the learning activities.

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# Enhanced Learning through Analogy in the Teaching of Cardiovascular System

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## ABSTRACT

This study examined the use of analogies incorporated in biology teaching for the topic 'transport in humans'. An action research approach was utilized, comprising both quantitative and qualitative analyses, in a 10th grade secondary school classroom setting. Parameters such as mean, standard deviation and the covariance analysis from both pre and post tests disseminated revealed that using analogy, as a method of teaching was statistically significant in improving the students' conceptual understandings and their critical thinking in constructing knowledge from their environment. The quantitative findings were qualitatively supported with the students' worksheets and outcomes from the interviews. The ability of the students to think critically was observed in the intervention. With the guidance from the teacher, students can reflect upon scientific concept that they learned by successfully bridging between the target and the analogue.

**Keywords:** Analogy, biology, conceptual understanding, constructive learning, critical thinking.

## INTRODUCTION

Comprehending difficult concepts, principles and theories could become easier in a classroom where teaching is carried out with analogy. Analogies provide simplified learning task and interpretations from the learners' existing knowledge. Analogies make the topic/concept familiar, common and easy to understand (Tairab, 1996). According to Orgill and Bodner (2004) whenever a new concept is introduced to students, it always becomes more easily understandable to them if it is linked to something they are already familiar with and come across it in their day-to-day life. Orgill and Bodner (2004) further emphasized that

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even though students are taught using analogies to understand, recall and visualize information from the class, yet these analogies are not presented in the class as efficiently as it should have been.

Treagust and Duit (2008) assert that analogy when recalled, helps to motivate students to become enthusiastic and talkative. Applying the use of analogies in classroom also helped students to overcome misconceptions (Hanson & Seheri-Jele, 2018). Orgill and Thomas (2007) suggest that using analogy in classrooms is significant due to its essential effect in communication, problem solving and creativity. In addition, Orgill and Thomas (2007) also suggest the incorporation of analogy in the different phases of the '5E Instructional Model' that comprised of Engage, Explore, Explain, Elaborate and Evaluate. The use of analogy in the 5E instructional phases enhances an inquiry-learning environment, making it easier to explain the concept, as students are interested to explore and focus on the concept (Bybee, 1993). For example, by relating the water tower analogy to cardiovascular system, the complexity of cardiovascular system is made easy by drawing comparison to cities water tower supply (Swain, 2000).

Herr (2007) emphasizes the benefits of employing teaching with analogies (TWA) strategy while minimizing the dangers of misconception. The TWA is a model originally introduced by Glynn, Duit and Thiele (1995), which works on the mapping of shared attributes. Each step in the TWA model is important. Depending on the teacher's style in approaching the steps in dealing with the specific scientific concept, a particular use of analogy will be modified accordingly (Harrison & Treagust, 1993).

Based on Piaget's view of constructivism, involving assimilation and accommodation of new knowledge over the students' past experience, the classroom instructions can be directed towards natural phenomena, which students encounter in their daily life. Analogy can also be considered as a Velcro tape, which will allow the new information to adhere to students' prior knowledge, in a way enabling them make sense of the scientific ideas (Smith & Abell, 2008). Harrison and Treagust (1993) concluded that presenting analogies with a systematic teaching model diminishes misconceptions.

### *Models of Analogy in the Classroom*

The general model of analogy teaching (GMAT) is a lengthy 9-step model that guides teachers to use of analogies in the classroom (Zeitoun, 1984). Assessing students' prior knowledge or general overview related to the analogical learning in general. Although this model gave an idea on using analogy in the classroom, yet it was not satisfactory the major weakness of being the complexity of measuring the analogical reasoning and identifying the cognitive complexity.

TWA model is another model proposed by Duit (1991), to guide teachers about the appropriate use of analogy and step-by-step procedure in introducing analogy as an alternative teaching strategy. It is a model that predominantly deals with analogy, based on textbooks instead of principles on pedagogy. There are six steps in the TWA model that needs to be followed in a sequence. The TWA model associates the term *target* to the new scientific concept and identifies the relevant features between the analogue and the target through mapping, and finally drawing conclusion in relation to the target and specifying the end-point of the analogy. Like the GMAT model, the TWA model also has drawbacks but these are easy to fix.

The Focus, Action and Reflection (FAR) guide enables a logical representation of analogies, and resembling itself to a more appropriate teaching arrangement with an action research approach (Harrison & Treagust, 2006). Additionally, the FAR model is based on constructivist theoretical framework. The model aimed to boost the benefits and diminish the constraints of analogies when it is used to teach science (Treagust et al., 1994). This model consists of three phases: focus, action and reflection. The foremost phase of this model is focus. In this phase the teachers are encouraged to focus on the science content to ascertain why it is difficult. The teacher use the analogue to ensure it is familiar to the students, and the students reflect on the ideas they already have about the science concept. The second phase is action. Any similarities and dissimilarities discussed between the concept in science and the analog takes place in this phase, which is either between the teachers and students, or students and students. The purpose here is to delineate limitations of the analogy. Final and third phase is reflect. In this phase drawing a conclusion is made, and the decision is to be made here whether the analogy is clear and useful or confusing. This has to be reflected upon by an improving the analogy based on the results. When the FAR model used in classroom, it can maximize the benefits of analogy. The other advantages of the FAR model are; it is comprised only three phases and enables active participation of students thus bringing in meaningful discussions.

*Types of Analogy*

There are a lot of ways to classify an analogy. Dagher (1995) distinguished five different analogies namely, a) compound analogy which uses more than one source, b) narrative analogy which is a story based analogy, similar to a story telling, c) procedural analogy which gives instructions for completing a task and very similar to science experimental procedures, d) peripheral analogy which is a teacher elaborated analogy usually created spontaneously in order to support the main analogy, and e) simple analogy which is associated with the target and shows clear bridging between the target and analog.

Analogies can be classified as student or teacher centered. *Student self-developed analogies* are that created by students to express their learning experiences. The teacher plays a big role in encouraging and motivating students to find new opportunities for a more advanced conceptual understanding. Such use of analogy integrated with guided practices and inquiry learning promote new tasks and let students to employ other thinking skills. Here, the teacher only facilitates an analogy by providing an analogical situation and the students infer the analogous attributes. Thus, it enables developing critical thinking to locate the attributes (Tairab, 1996). The practice of guided inquiry with analogy also helps in a significant reduction in the gap in acquisition of science process skills between the genders (Nworgu & Otum, 2013). A *teacher-centered analogy* is usually helpful in learning new tasks and ruled by the teacher since this form of analogy is both created and presented by the teacher. The application and conceptual understanding in the learning are less effective in the teacher-centered analogy.

Duit (1991) organized analogy into four groups namely *pictorial, personal, bridging, and multiple* analogies. Pictorial analogy is one of the most common types of analogy used by teachers and textbooks. The pictorial analogies are easier to be understood by the students and to be related as an analog. While personal analogies are those students relate an abstract scientific concept to students' real world environment. Duit (1991) also claimed that pictorial analogy is more enjoyable and easily understood analogy by students as well as motivates them.

*Using Analogy in Teaching and Learning of Cardiovascular System*

When teaching other lessons or concepts, different analogies can be identified according to their complexity, such as simple analogies, enriched analogies, and extended analogies, (Ahmed & Cheong, 2006). Simple analogies are those of which the teachers identified the target simply as the analogue without any further effort. An example of a simple analogy is a factory is like a cell. Enriched analogies include one or more analogies to explain the target concept. Enriched analogies are known to be the most appreciated by teachers. Lastly, the extended analogies include the inclusion of one or more analogies in order to explain a target, similar to enriched analogy but the main difference is on the use of several attributes in describing the target (Ahmed & Cheong, 2006). As teachers support the use of complex analogies by utilizing them in their teaching as a source of critical thinking for the students, the use of complex analogies would encourage student discussions and the students' participation made them learn better.

In this paper, the use of analogy to teach transport in human, also known as the cardiovascular system, is explored. Extended literature review reveals that there is limited number of published and focused studies in this field. The one and only published study is by Swain (2000), which relates the water tower analogy to cardiovascular system by drawing comparison to cities water tower supply. Swain (2000) claims that the presented analogy had successfully made the concept easier to understand. However the analogy came with a need of clear justification on the possible misconceptions that might occur as cardiovascular system is a closed system that is not affected by gravity, whereas the water tower system is an open system that utilizes gravity for water to flow downwards. Moreover, based on the complexity of the analogue, students' thorough understanding of the analogue plays a very crucial role in further thoughtfulness of the target and hence empowering the teacher in using the appropriate analogy. It is therefore the responsibility of the teacher to identify an appropriate analogue familiar to the students. This paper discusses extended type of analogy that contributes and takes into consideration various analogies in improving the teaching and learning of the cardiovascular system topic.

It should be emphasized again that there is paucity in the literature on the use of analogy to teach cardiovascular systems except for the water tower analogy described by Swain (2000). Therefore, the current study provides support for Swain's study on the effectiveness of using the water tower analogy for the teaching of cardiovascular system.

## METHODOLOGY

This study employed an action research design approach incorporating the use of the mixed-methods (quantitative and qualitative) analyses. The quantitative analysis measurement included the analysis of pre and post tests using statistical methods. The study was further driven using qualitative analysis of guided worksheet questions, opinion polls and interviews. The interviewees were chosen based on the students' performance scores in their pre and post-tests, ranging from the high ability, low ability and average ability student participants. Figure 1 is the graphic representation of the methodology followed during the study of action research. Two research questions that guided this study are as follows:

1. What is/are the effect(s) of teaching biology using analogy on the achievement of $10^{th}$ grade students on the concept(s) of cardiovascular system?
2. Does the analogy enhance the students' critical thinking in constructing knowledge from their learning?

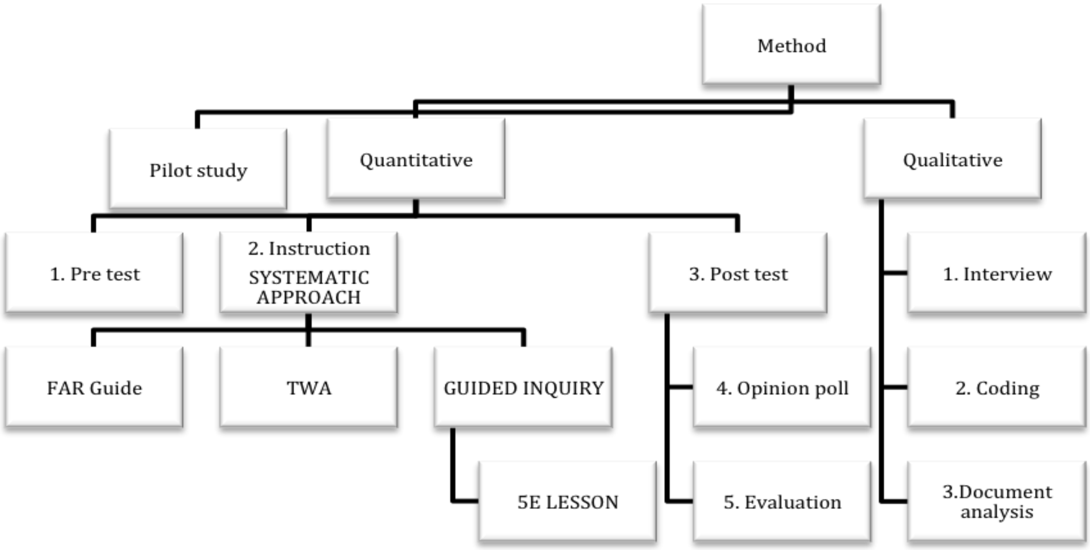


***Figure 1.*** Methodology of the action research

### a) Sample

The 21 student participants were from one 10th grade class. There were 14 to 15 years old students with mixed learning ability. The number of girls-to-boys was found to be in the ratio of 13:8. Culturally, majority of the students were local Bruneians and few being Chinese descendants staying in Brunei. English language was a secondary language for these students. The sample site was a secondary school located in the Brunei-Muara district.

### b) Instruments

The test papers were categorized into two sections: multiple choices questions and essay-type structured questions. Each section was 15 points, thus totaling to 30 points for each test paper. An opinion poll was also distributed to assist in both quantitative and qualitative analyses. Student participants were interviewed based on the post-test performances; two students from each achieving categories (high, medium and low) were interviewed.

The validity of the test paper was checked, followed by content reliability by a specialist of the subject biology, using modified questions based on the General Certificate of Education Ordinary syllabus for Biology (syllabus code 5090). A pilot study of the test paper was carried in determining the difficulty index and reliability of the test through SPSS packet program.

### c) Data Analysis

Students were taught the biology topic on ‘Transport in man: The human cardiovascular system’. Several subtopics were chosen such as double circulation, the flow of blood around the body, blood components and the working of valves in a vein, different chambers of heart, and rejection of organ by the body during tissue transplant. First the pre-test data was collected to determine students’ understanding about the content taught without the use of analogy. Then, the same scientific concepts were dealt with the help of simple analogies prepared by the researchers.

After the pre-test, the same topics are taught again with the help of systematic approach to analogy. The FAR guide and the TWA method incorporated in the 5E lesson plans. Teacher facilitated the students in forming the analogy between the target and the analogue by using these lesson plans. During the intervention, the subject of cardiovascular system was taught through analogy method. All the activities were done in the teaching environment related to practicing analogy, PowerPoint presentations, and lesson plans incorporated into 5E learning cycle. The different types of analogies were prepared after a careful study on the understandability, plausibility, and prolificacy of the conceptual understanding. The same test was applied as the post-test to determine any changes in student's conceptual understanding. Sample t-test for independent and dependent groups in SPSS packet program was used to analyze the data obtained.

## FINDINGS

The pre and post-test scores were evaluated to observe changes on the students' conceptual understanding on the lesson of cardiovascular system before and after the intervention with analogy. Statistical test of dependent group's t-test was applied in determining whether there is any significant difference between the pre- and post-test groups. The test results were presented in Table 1.

**Table 1.** *Dependent group's t-test in analyzing pre- and post-test scores on the effects of teaching using analogy*

| Group | N | Mean | S | SD | t-value | p-value* | ETA$^2$ |
|---|---|---|---|---|---|---|---|
| Pre-test | 21 | 11.33 | 4.36 | 3.35 | 11.64 | 0.001 | 0.74 |
| Post-test | 21 | 19.86 | 3.44 | | | | |

*p<0.05

As seen in Table 1, the group's average score of the pre-test is 11.33 with a standard deviation of 4.36, whereas the average score of the post-test is 19.86 with a standard deviation of 3.44. The student t-test value achieved was t=11.64, with a p-value less than 0.001. Since the p-value is less than 0.05 implies that there is a significant difference between the two test scores. With the increase of the post-test average scores, it also depicted that teaching biology concept using analogy does have a positive impact.

Consequently, an independent group t-test was carried out to determine if the understanding towards the taught scientific concept on the topic of cardiovascular system before and after the intervention of analogy differed according to gender. The results for the pre-test are given in Table 2 and the results for the post-test presented in Table 3.

**Table 2.** *Independent group t-test in comparing the pre-test scores by gender*

| Gender | N | Mean | S | t-value | p-value | ETA$^2$ |
|---|---|---|---|---|---|---|
| Male | 8 | 11.00 | 5.59 | 0.144 | 0.887 | 0.001 |
| Female | 13 | 11.30 | 3.92 | | | |

As seen in Table 2, pre-test average scores for both male and female students on the topic of cardiovascular system before the intervention indicates a close distribution to each other. The students' pre-test scores t=.144 with p-value of 0.887 indicates that the students' understanding of cardiovascular system before the intervention with analogy is significantly similar to each other regardless of the gender differences.

**Table 3.** *Independent group t-test in comparing the post-test scores by gender*

| Gender | N | Mean | S | t-value | p-value | $ETA^2$ |
|---|---|---|---|---|---|---|
| Male | 8 | 21.00 | 4.20 | -1.026 | 0.318 | 0.055 |
| Female | 13 | 19.30 | 3.11 | | | |

Similar to earlier findings, the male and female students' post-test average scores does not indicate any significant difference as indicated by the p-value of more than 0.05 in Table 3. The average score obtained by the male students is 21.0, whilst the female students scored 19.3. The result obtained suggests that students' understanding towards the taught biology concepts before and after the intervention is equal for both genders.

Concurring with the findings by Orgill and Bodner (2004), the findings from this study suggests the use of analogies may be applied when there are difficulties and challenges in the target concepts, and when new target concepts are introduced that cannot be visualized. Accordingly, when an analogy is used in a lesson it enhances students' interests and attitudes in their studies (Al-Hinai & Al-Balushi, 2015; Paris & Glynn, 2004).

Lemke (1990), and Hanson and Seheri-Jele (2018) asserted that the students would pay more attention to an analogy, which are familiar to them compared to unfamiliar contexts containing scientific terms. Similarly, Orgill and Bodner (2004) supported that most students preferred the use of analogies by their teachers in explaining or introducing concepts that were complex. Additionally, these students found the use analogies in learning as entertaining and they were able to retain and understand the topic. Figure 2 shows questions posed to the participating students in this present study after experiencing lessons with the use of analogy.

Name:____________________ Class:________

Unit 7:____________________ Date: ________

Answer the following in only **Yes or NO**

| No | | Yes / No |
|---|---|---|
| 1 | From the analogies during the lesson on Transport in Human, do you feel like using analogy more often for your future lessons? | |
| 2 | Did the use of the analogy in your lesson of "Transport in Human" help increase your understanding of the topic? | |
| 3 | Has the analogy been helpful to you in removing your doubts (not sure of) or other prior ideas about this topic? | |
| 4 | Were you able to visualize (as in see) the concepts while doing the study with analogy? For example, plumbing system of your house is like the cardiovascular system of your body. | |
| 5 | Would you recommend this use of analogies to your teachers and friends? | |

***Figure 2.*** Questions posed to participating students

According to data from the opinion polls, majority of the participating students preferred lessons with the use of analogy (see Table 4).

**Table 4.** *Overall opinions of the participating students on the use of analogy in learning*

| Responses | Q1 | Q2 | Q3 | Q4 | Q5 |
|---|---|---|---|---|---|
| Yes | 16 (76%) | 16 (76%) | 14 (67%) | 13 (62%) | 15 (71%) |
| No | 5 (24%) | 5 (24%) | 7 (33%) | 8 (38%) | 6 (29%) |

Figures 3, 4a and 4b are samples of the students' worksheets that resulted from the use of analogy. The worksheet in Figures 4a and 4b required students to sketch how the highway compares with the blood in the blood vessels of their body. The worksheets also explored students' ability to produce the illustrations entail a high order of thinking. From the responses and the sketches obtained, all three students displayed the ability to think critically, and subsequently categorized as high achieving students.

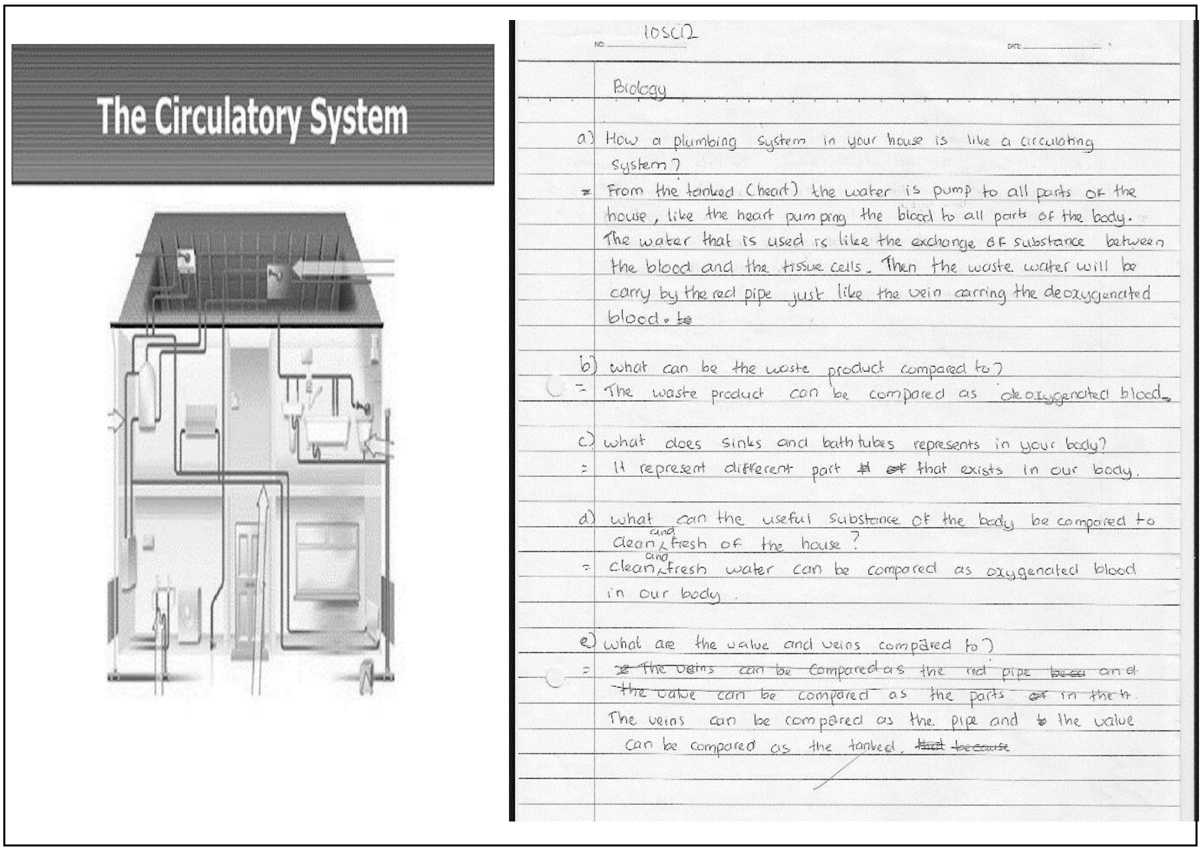


***Figure 3.*** Responses from Student A on the comparison of plumbing system of a house to that of blood transport system of human body

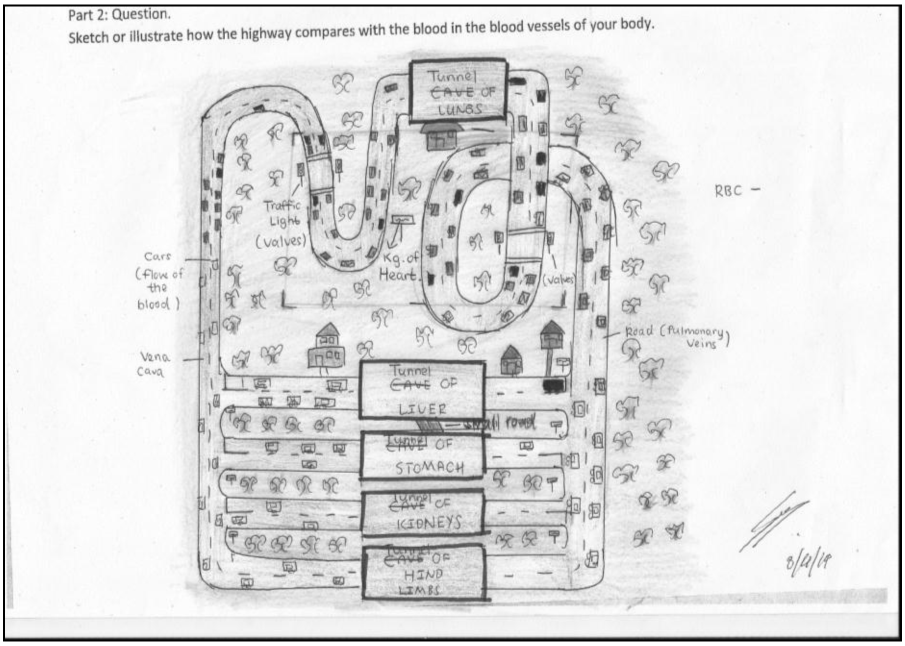


***Figure 4a.*** Sketches made by Student B in contrasting the 'road highway' with regards to the blood vessels of the body

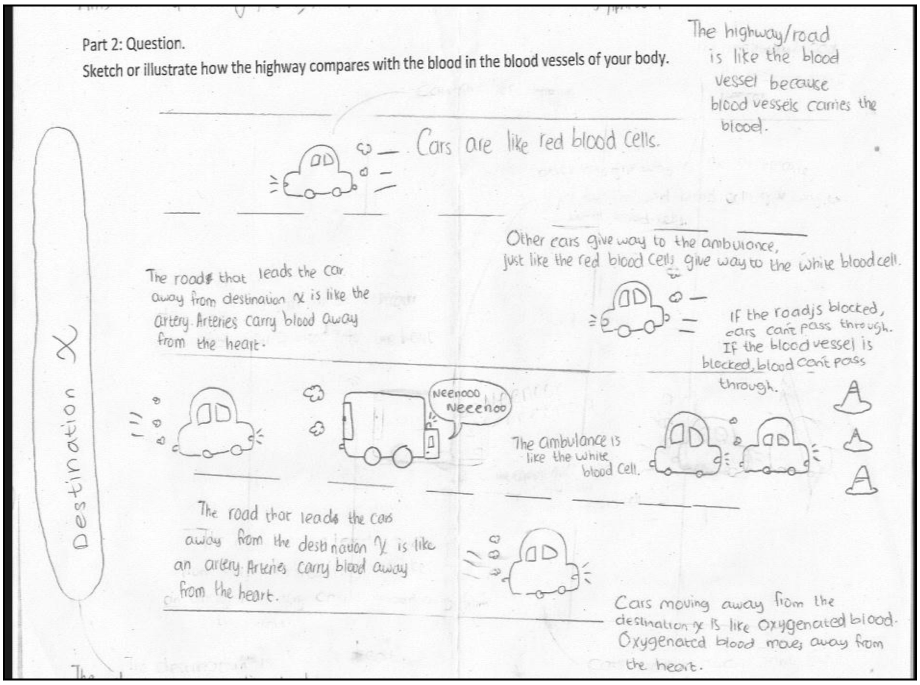


***Figure 4b.*** Sketches made by Student C in contrasting the 'road highway' with regards to the blood vessels of the body

Upon interviewing two of the high achieving students, they stated that they enjoyed learning with using analogies. One of the students further stated "*I found it easy to relate the target from the second analogy onwards. At first when it was introduced I found it was difficult and confusing, but later on as more of analogies were compared I found it was fun. I was able to compare the circulatory system of the human body to the plumbing system of the house*". However, the students who where categorized as medium achievers said they did not like analogy. They preferred to study without using a lot of analogy and getting notes from the teacher.

The students' answers during the interview were also analyzed with their test papers for their explanations on the biological concept of cardiovascular system. The important finding obtained from the study is the development of critical thinking in students when they were asked to illustrate an analogy in their own words.

## CONCLUSIONS

The use of anology in teaching the studied concept was found to instigate understanding and critical thinking in students as compared to the convetional teaching method. Another important aspect noted was that students are able to grasp analogies easily when discussed in groups. For most of the students, they were able to associate the anlogue to the target by differentiating and comparing different attributes. There were no observable misconceptions that emerged from this intervention, which could be rectified by discussions in the classroom itself. The remarkable surge in the scores of the post-test from the pre-test showed that analogies used in the intervention were effective in contributing understanding of the concepts.

It was also found that students do think critically and creatively when illustrating analogy. Students tend to be attentive as well as enjoyed learning the topic when it was discussed as these easily relates to their surrounding. Nevertheless, the students' English proficency is also very much important in order to actively take part in the discussions relating the target to the analogue. Therefore, trained teachers with the proper channel of introducing analogy may able to boost the students' overall understanding.

Effectiveness of using analogy in promoting students' understanding is positively taken in to enhance students' critical thinking in constructing knowledge from their environment. Implementing analogy for the first time to a class was proven to be challenging, however, with guidance and help from a trained teacher, its use could be effective towards the target concept by accommodating it in teaching techniques successfully. The findings showed that analogy resources do not need to be from textbooks. Resources can also be modified to students' need in the classroom. This study also throws light on the fact that students understand those analogies better with which they are more accustomed to in their day-to-day life.

The ability of the students to think critically was also studied during this intervention. It was touched upon the fact that students with guidance from the teacher can reflect upon scientific concept to be learnt by successfully bridging between the target and the analogue. This ability of critical thinking will go a long way in their reasoning and analyzing skills in the future.

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# Improving Basic Science Process Skills Through Inquiry-Based Approach in Learning Science for Early Elementary Students

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## ABSTRACT

The aim of the study was to examine the improvement of basic science process skills among second graders in science learning through an inquiry-based approach. The participants were 23 students from a second graders class. Participants were with the age around seven years old. The 5E model of inquiry-based approach was used to teach science. Mixed method approach used in the study. The qualitative data were collected through classroom observation, teacher interviews, and students' works. The quantitative data were collected from performance tests measured by using a rating scale instrument. The improvement of basic science process skills were examined through descriptive statistic and t-tests. The study showed that the basic science process skills improved after the intervention of learning. The study also revealed the factors contributed to the inquiry-based approach of science learning to develop the basic science process skills, such as the use of worksheets, singing a song, and the interactions with both peers and teacher.

**Keywords:** Science process skills, inquiry-based approach, 5E model, science teaching, early elementary

## INTRODUCTION

Teaching science to young children is important. Science provides children opportunities to grow their innate curiosity and discover about the natural world. By learning science, children can strengthen their problem-solving skills (Carin, Bass, & Contant, 2005). It also contributes to developing a positive attitude toward science. Since the attitudes begin to grow at an early age, it could affect later success in learning science (Eshach, 2006). Children's ability to explore their direct surroundings can strengthen their attitude and skills which contribute to the children becoming lifelong learners (Brunton & Thornton, 2010).

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Science education, especially practical activities, are suggested to be included in the early childhood education program (Mirzaie, Hamidi, & Anaraki, 2009).

Science learning has three major aspects; a body of knowledge, a method or process and a way of knowing. Science as a body of knowledge refers to science products such as information, concepts, and facts. Science also involves a set of methods or processes. The method is the process in which a body of knowledge is produced. In the method or process, students learn how to do science through exploration by observing, classifying objects, measuring and so on. Furthermore, science also is as a way of knowing (Bell, 2008; Rezba, Sprague, McDonnough, & Matkins, 2007). Learning how to do science is more beneficial for children than learning the facts, concepts, and theories (Martin, 2009).

Science process skills are physical and mental skills to collect information and organize them in several ways. These skills can be used in predicting and explaining phenomena, and solving problem (Carin et al., 2005). The science process skills are used to process new information in concrete learning. They also can build new concepts and new understandings of science (Charlesworth & Lind, 2010). Science process skills are the skills that scientists use in their study (Bentley, Ebert II, & Ebert, 2007; Martin, 2009). There are two categories of science process skills; basic process, and integrated process. The basic science process skills include observing, classifying, measuring, inferring, predicting, and communicating (Bentley et al., 2007; Martin, 2009). The integrated science process skills involve identifying and controlling variable, formulating and testing hypothesis, interpreting data, defining operationally, experimenting, and constructing models (Martin, 2009).

Observation is a process to collect information about the world using senses (Carin et al., 2005; Charlesworth & Lind, 2010; Morrison, 2012). Observation is the first step in collecting information and the only way to gain knowledge about the world (Charlesworth & Lind, 2010). Children observe using their senses to perceive objects, events, properties and behavior (Bentley et al., 2007). During observing the objects, they practice using various senses such as sound, sight, smell, touch, and taste (Charlesworth & Lind, 2010; Martin, 2009; Rezba et al., 2007). Children can also use instruments to support their senses during observation, such as using magnifying glasses, telescope, and microphones (Carin et al, 2005).

Observation skill is the core of science learning (Jackman, 2012; Martin, 2009) and often considered being the most significant skill of science process (Charlesworth & Lind, 2010; Johnston, 2005). Therefore, it is the most crucial scientific skill to be developed in elementary schools. Children need to practice this skill appropriately to make learning experiences stored in their long-term memory. Thus it will be better for children to create a connection with the new things they explore (Martin, 2009).

From observations, students can proceed to the process of comparing and classifying objects (Jackman, 2012). Classification skill is the process of grouping objects or events into categories based on characters or properties of objects or events (Bentley et al., 2007). Classification skill is very useful in organizing information in science (Carin et al., 2005). Children learn classification by grouping and sorting real objects. They can sort the objects based on their observation. Students can initially group objects by one feature. For example, they can sort objects based on color, size, or shape (Charlesworth & Lind, 2010). Students can strengthen the ability to classify objects with practice and appropriate coaching (Bentley et al., 2007).

Measuring is an act of doing quantitative observations. Measuring can be accomplished by comparing an object, event or other phenomena with a standard or a non-standard unit (Hammerman, 2006). During an activity, the children use quantities or number to describe objects or events (Bentley et al., 2007). Children can use measurements to enhance the description, prediction, and explanation of phenomena (Carin et al, 2005). Children can learn basic measurements such as length, volume, weight, temperature and time. They can measure using standard units and non-standard or conventional units (Martin, 2009).

Mastering the science process skills is important for future understanding in science and these skills are beneficial in daily life for solving problems as well (Charlesworth & Lind, 2010). Initial learning is a base for students to develop more understanding of science process and problem solving in later education (Aka, Güven, & Aydoğdu, 2010). The science process skills help students to understand phenomena, answer questions, develop theories and discover information (Martin, 2009). They are essential in developing ideas (Harlen & Qualter, 2004) and they increase academic achievement in science learning (Aktamis & Ergin, 2008). Özgelen's (2012) study shows that science process skills are related to cognitive development. These skills are correlated with the skills of logical thinking (Ismail & Jusoh, 2001). Another study shows that the skills performance of children is related to several factors such as gender, grade level, economic background, mother's educational background, and the number of the family (Aydinli et al., 2011; Dökme & Aydinli, 2009).

In Indonesia at lower grades of elementary school, science learning is integrated into other disciplines such as language within thematic learning and science is not implemented as a separate discipline. Nevertheless, science is still considered being important learning at early elementary schools. Schools apply thematic learning and some themes are very relevant to science. However, since science is generally integrated with language learning, science process skills do not develop adequately. Thus, science learning has been focused more on the aspect of the body of knowledge. In other words, students learn more science concepts, facts, and information by reading textbooks rather than doing science as a process. Furthermore, a preliminary observation in a private elementary school shows that a majority of students at second graders has a relatively low level of basic science process skills.

Children need to learn and develop the science process skills by practicing them in science learning. Teachers should master the science process skills and teaching strategies to help students to develop these skills (Ango, 2002). Science learning plan should include practicing science process skills to ensure the students obtaining the skills. A study implied that without planning of lesson and guidance, students might not develop the science process skills (Rauf, Rasul, Mansor, Othman, & Lyndon, 2013). Instruction to develop science process skills should also support the learning about the nature of science (Huber & Moore, 2001). Therefore, practicing the skills can be applied in science learning through an investigation of nature or material.

Inquiry is a process to find information by asking questions (Bentley et al., 2007) and a scientific process in exploration. Learning through inquiry involves asking questions, conducting investigations and collecting data. During an active exploration, students use critical, logical and creative thinking (Llewellyn, 2002). There are two main aspects of science learning through inquiry; asking questions and seeking answers through data analysis (Bell, 2008). Learning through the inquiry-based approach involves children in exploration activities which leads them to ask questions, test the ideas, and discover the answer (Ansbery & Morgan, 2007).

Children can build their potential by strengthening their scientific idea through inquiry investigation (Blake, 2009). Scientific inquiry means incorporating science process with other aspects such as scientific reasoning, scientific knowledge and critical thinking (Lederman, Lederman, & Antink, 2013). Duran and Dökme's study (2016) reveals that inquiry-based learning affects students' critical thinking significantly. Another study also reveals that students who are taught through an inquiry-based approach have higher academic achievement than those who are taught traditionally (Abdi, 2014; Aktamiş, Hiğde, & Özden, 2016). An inquiry-based project also increases the student's interest in science learning (Akinoglu, 2008). Students enjoy more learning through inquiry-based science than traditional science learning (Suduc, Bizoi, & Gorghiu, 2015). Moreover, students who learn science through 5E model of inquiry-based approach have a positive attitude toward the subject of science (Ergýn, Kanli, & Ünsal, 2008).

Rezba, Auldridge, and Rhea (1999), (as cited in Bell, Smetana, & Binns, 2005) developed different levels of inquiry learning, such as confirmation, structured inquiry, guided inquiry, and open inquiry. In confirmation level, students confirm the principle they have learned by following given question and procedures. In structured inquiry level, the teacher provides question and procedures, and students follow these procedures to find the answer. In guided inquiry level, students use their own procedures to answer the teacher's questions. Open inquiry is the highest level which students design the procedures to answer their own question. Students can begin with the low level and gradually develop to a higher level of inquiry (Bell et al., 2005).

One of the models of inquiry-based approach of science learning is 5E. The 5E model follows constructivist theory (Chitman-Booker & Kopp, 2013). The 5E model consists of 5 phases; engagement, exploration, explanation, elaboration, and evaluation (Ansberry & Morgan, 2007; Carin et al., 2005; Chitman-Booker & Kopp, 2013). Learning starts with the engagement phase which supposes to generate the students' interest. At this stage, a question for investigation is raised. Students then proceed to the exploration phase, where they plan and carry out the investigation to collect evidence for answering the question. During this phase, students learn through activities as a concrete experience. Explanation phase happens when students construct their scientific explanation. At this stage, students attempt to answer the initial question. During the elaboration phase, students apply new knowledge in another situation. Finally, the evaluation phase occurs as the student's new knowledge and new understanding are evaluated (Carin et al., 2005). The 5E model can be implemented as a cycle or as a linear process (Ansberry & Morgan, 2007).

A study shows that inquiry-based learning can improve the science process skills among fifth graders (Şimşek & Kabapınar, 2010). Another study reveals that inquiry-based learning can enhance science process skills among fourth, fifth and sixth grades (10-12 age group) (Ergül et al., 2011). An inquiry-based approach enhances the science process skill among secondary school students (Athuman, 2017). Previous research studied secondary and higher grades of elementary school students. This study will examine lower graders who are still in the age range of early childhood. The aim of the study is to examine the improvement of basic science process skills among second graders through inquiry-based approach in science learning. In line with this aim, two research questions were addressed: (1) Is there an improvement of the basic science process skills among second graders in science learning through inquiry-based approach? (2) How factors affect inquiry-based science learning in improving the basic science process skills?

The importance of the study as follows: (1) The study can contribute to planning and implementing inquiry-based approach of science learning to increase the basic science process skills, especially in early elementary students. (2) The study can contribute in finding out the improvements of the basic science process skills through the inquiry-based approach in science learning (3) The study describes factors contributing to the inquiry-based approach to improve the basic science process skills.

## METHODS

The study used mixed methods. Since the objective of the study is to improve basic science process skills, the action research method was employed in this study. Action research can be carried out with both qualitative and quantitative method (Mertler, 2017). Action research is a cyclic process. In each cycle, there were stages of (i) plan, (ii) act and observe, (iii) reflect (Kemmis & Mc Taggard, 1988). The main purpose of action research is to improve educational practice. The action research is a constructive inquiry. By doing each step of the action research such as planning, acting, and evaluating, researcher constructs his or her knowledge about the particular issue (Koshy, 2010). As the intervention, each cycle consisted of 10 lessons using inquiry-based approach of science learning. The inquiry model of 5E was implemented during learning activities. The beginning of the research we focused on how to plan and implement science learning through the inquiry-based approach to increase basic science process skills for early elementary students. By using action research method, researchers collaborated with the classroom teacher to gain practical knowledge and a better understanding of the learning process. Then for better achievement results, we modified the instruction along the intervention based on reflection of the learning process.

The first part of the research was to examine the improvement of basic science process skills in learning science through the inquiry-based approach. Quantitative research approach was employed in this part of the study. The results between pre-test and post-test were compared. The significance of the improvement of the science process skills was analyzed using t-test. A descriptive qualitative approach was used in the second part of the study. The factors supporting the inquiry-based approach to improve basic science process skills were determined.

### a) Participants

The study was carried out in an elementary school. The school was located in a suburban region of Jakarta metropolitan city. Participants were 23 second grade students aged around seven years old. 15 students were male and seven students were female.

### b) Data Collection Techniques and Data Analysis

For the qualitative part of this study, data were collected by taking field notes through observation, students worksheets and classroom teacher interviews. These qualitative data were analyzed which followed to three main steps; data reduction, data display and conclusion drawing (Miles & Huberman, 1994).

For the quantitative part of this study, a rating scale of performance instrument was developed for the assessment of the basic science process skills for second graders based on the literature. To establish content validity, the items of the instrument were given to four faculty members. Two of the faculty members were from early childhood education and the other two were from science education. All faculty members were asked to judge the appropriateness of each item and its relevance to the skills being measured. Each item of instruments was refined based on the faculty members' feedback. This instrument of performance tasks was used to assess the skill of observation, classification, and measurements for second graders in elementary school. Each performance task involved hands-on activities and they were applied to the students individually. The individual total scores of the result were categorized into four levels for the skill as shown in Table 1, and each level was represented by a grade (A, B, C, D).

**Table 1**. *Grades and performance levels of the science process skills base on ranges of scores*

| Score Range | Grade | Performance level |
|---|---|---|
| 82 - 100 | A | Advanced |
| 64 - 81 | B | Proficient |
| 45 - 63 | C | Developing |
| $\leq$ 44 | D | Beginning |

The science process skills were assessed before and after the intervention of each cycle of this action research. The enhancement of the skills was analyzed through descriptive statistic which was presented data by charts of the students' skills grade before and after the implementation of the learning. Moreover, the significance of improvement of science process skills was analyzed using t-tests of the scores from pre-test and post-test. SPSS software was used to do the paired t-test analysis.

In this study, the minimum-passing criterion was established in accordance to the school standard. The students were acknowledged to meet the minimum criterion of the average score of overall science process skills acquired was $\geq$ 78. The implementation of learning was considered successful when the majority of students (e.g. $\geq$70%) in the class had obtained the score of the minimum criterion of mastery learning.

### c) Research Procedures

#### *The planning*

Science learning through structured inquiry-based approach was planned before the implementation. In this structured inquiry-based approach, a question and procedures for finding solutions were prepared by the teacher. The plan was based on the inquiry-based learning model of 5E which has the stages of engagement, exploration, explanation, elaboration, and evaluation. Relevant activities that involve basic science process skills were integrated into the exploration phase of learning. Since the school applied thematic learning, science activities had been planned based on relevant themes to science. The activities were integrated into four themes: (1) Playing in My Neighborhood, (2) Water, Earth, and Sun, (3) Caring for Animals and Plants, (4) I and My School. There were 10 lessons planned for each cycle and these were implemented as simple scientific investigations.

There were three kinds of investigations prepared for learning activities such as a simple experiment, descriptive or classificatory investigation. To develop observation skill, the objects or materials for the descriptive investigation were selected based on their properties. The objects should be representative to support children in using various senses. It should also support a quantitative observation such as counting seeds, flowers, and petals. In classification activities, choosing objects for hands-on activities was based on difference shape, color, and size. Those three basic characters were familiar in the daily life of young children. A collection of leaves, buttons, and pebbles were prepared for children to learn classification. To develop measuring skill, simple investigations were designed that involve measurements such as length and temperatures. Some measurements were integrated into observation skills activities. Thus, the children could learn to measure some objects they had observed.

Furthermore, worksheets were developed to help the students using the basic science process skills. The worksheets were provided as simple instructions written in easy language and relevant illustrations for young students. The worksheets were developed to guide the students in doing the investigation involving basic science process skills. Since students used to learn by reading textbooks, using worksheets while exploring through hands-on activities helped to move from expository learner to be more inquiry learner.

#### *The implementation*

Inquiry-based approach was implemented using the 5E model. The model has phases of engagement, exploration, explanation, elaboration, and evaluation. The purpose of the engagement phase was to generate the students' interest. The teacher began this phase by asking questions. These questions were not only relevant to the thematic topic but also to students' daily activities. These questions would direct the students to a short discussion. The discussion allowed the teacher to find out what students already know. The teacher could explain the new knowledge that students needed. Furthermore, the inquiry question was raised by the teacher which leads the students to explore and find the answer.

Exploration was the phase when the students explore the objects to find the solution or answer. Explanation phase occurred when students formulated their answer. In these two phases, the students worked in small groups, explored the objects together with their peers and give the answers. They practiced exploring objects appropriately by following simple instruction on the worksheets. However, sometimes the teacher had to explain or demonstrate how to use the basic science process skills when students needed. While doing exploration, the students discussed the answers within their group. Furthermore, they filled out the worksheets given individually. In this study, generally, the elaboration phase did not occur in the same activity or lesson. Thus, new knowledge or skills might be elaborated to the next lessons. Moreover, the achievement of the skills was evaluated through the students' performance and worksheets. During the implementation of science learning, the learning process was observed and these observations resulted in data for the qualitative study.

Finally, the whole learning process of the first cycle was reflected and the students' achievement of the basic science process skills was evaluated. The implementation of learning was considered successful when a majority of the class had obtained the score of the minimum criterion of mastery learning established by the school. When the implementation of learning was not successful in the first cycle, the second cycle was proceeded. Based on the reflection of the whole learning process of the first cycle, the instruction to be implemented for the second cycle could be revised for better achievement.

During the second cycle, the implementation of inquiry-based learning of the 5E model was continued within thematic learning. However, the use of detailed worksheets was minimized to allow the students to work more independently in employing the science process skills. A special song with lyrics about observation skill was prepared. Students practiced singing for a few days before the investigation. By singing the song, the students were encouraged to use observation skill appropriately.

## FINDINGS

### a) The Improvement of the Basic Science Process Skills

Pre and post-tests of the performance assessment scores were used for quantitative data analysis. Pre-tests applied before the implementation of the first cycle and posts test applied after the implementation of the second cycle. The total individual scores of the skills were categorized to the four levels of the skills; advanced, proficient, developing, and beginning and these levels were represented as grade A, B, C, or D.

#### *Pre-test results*

Pre-test results of the assessment of basic science process skills showed that majority of students achieved grade C or D. That means some students had the performance level of developing the skills, while other students were still in the beginning level. There was a small portion of students achieved grade B - proficient performance- for both observation and classification skill (see Figure 1).

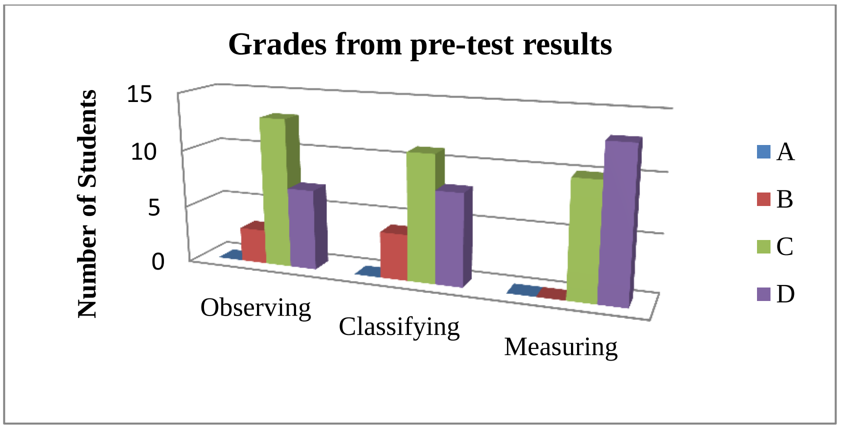


***Figure 1.*** Grades from pre-test results

***Post-test results for the first cycle***

The post-test results of the first cycle revealed that majority of students achieved grade B for all basic science process skills. Thus, the students achieved the proficient level of performance. However, for the observation skill, there were also many students obtaining grade A - an advanced level of performance (see Figure 2).

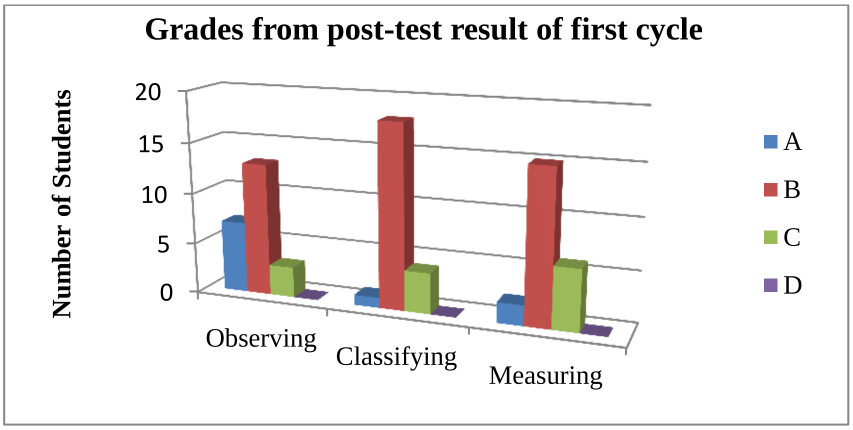


***Figure 2***. Grades from post-test results of the first cycle

The minimum criterion of the score for mastery learning of was ≥ 78 based on the standard established by the school. Data showed that the majority of students did not meet the minimum standard for the basic science process skills. The percentage of the students meet the minimum criterion is presented in Table 2.

**Table 2.** *Percentage of students meeting the minimum passing criterion in the first cycle.*

| **Science Process Skills** | **%** |
|---|---|
| Observation | 39% |
| Classification | 35% |
| Measuring | 26% |
| Mean | 33% |

***Post-test results for the second cycle***

The post-test results showed that majority of students achieved grade A. Results revealed that students obtained the advanced level of performance. However, many students also obtained grade B - in the proficient level of performance (see Figure 3).

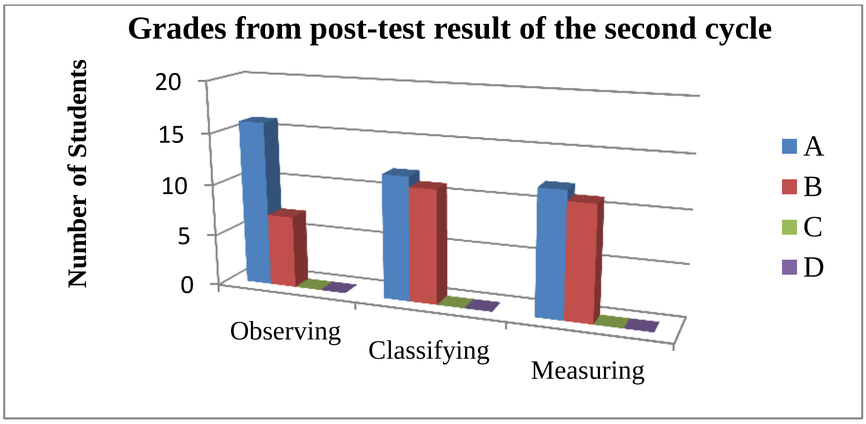


***Figure 3***. Grades from post-test results of the second cycle

The data also showed that, in the post-tests, majority of the students reached the scores of $\geq$ 78 which was the minimum standard for the passing criterion. The percentage of the class member reach the minimum standard for each skill is presented in Table 3.

**Table 3.** *Percentage of students meeting the minimum passing criterion in the second cycle*

| Science Process Skills | % |
|---|---|
| Observation | 82 |
| Classification | 96 |
| Measurement | 100 |
| Mean | 93 |

***The significance of improvement of the basic science process skills***

The improvement of the basic science process skills was examined through paired t-tests of the scores results of the assessments of pre and post-tests of inquiry-based science learning. Data showed that there was a significant improvement between pre and post-test for observation, classification and measurement skills (see Table 4).

**Table 4.** *The t-test of pre and post measurements of science process skills*

| Skills | Variable | N | Mean | Sd | Sig |
|---|---|---|---|---|---|
| Observation | Pre-test | 23 | 54.2 | 13.2 | 0.00 |
| | Post-test | 23 | 87.6 | 9.2 | |
| Classification | Pre-test | 23 | 53.5 | 9.9 | 0.00 |
| | Post-test | 23 | 86.4 | 6.4 | |
| Measurement | Pre-test | 23 | 52.8 | 7.5 | 0.00 |
| | Post-test | 23 | 88.6 | 4.6 | |

### b) Factors Contributing to the Inquiry-Based Approach to Improve the Basic Science Process Skills

The second research question was how factors affect science learning through inquiry-based approach to improve the basic science process skills. In addition to science investigation using hands-on activities, there were several factors contributed to the inquiry-based approach to increase the basic science process skills. These factors included the using of worksheets, singing a special song, and interacting with both peers and teacher.

Students began to use basic science process skills by following simple written instruction on the worksheets during the first cycle of research. The worksheets were provided with relevant illustrations to ensure the students to use these skills. In observing the objects, students followed the written instruction to be able to use their various senses and to make quantitative observations. Students simply provide their short answers by filling out worksheets. Students also followed the written instruction to find out the difference and similarities between the objects. This enables them to enhance their classification skills. Similarly, they measured some objects they observed as it was directed on the worksheets.

Another important factor which helped the students to improve observation skill was the use of a song. In the second cycle, the students were provided with a song with lyrics about observing objects properly. By singing the song before doing science investigation, students were encouraged to use various senses and make quantitative observations. Some of the students also sang the song during the investigation when they needed to recall the procedures. Thus, students were able to practice the skill more independently without written guidance.

The study revealed that students learned basic science process skills through interaction among their peers during the investigation. Since the students carried out investigation within small groups, they could learn from working cooperatively with each other. For example, a student told his friend how to observe a plant's characters. He showed his friend how to rub the leaf surface. Another student asked her friend to smell an object. Thus, she encouraged her friend to use various senses during observation. Some students also learn by observing their friend while the friend was employing the skills. For example, a student saw his friend counting the number of leaves for quantitative observation, then he did the same thing.

During the investigation, some students learned practicing basic science process skills from the teacher. In addition to the using of structured inquiry-based approach, students learn the skills through a confirmation level of inquiry. Students gained new knowledge about how to observe, classify and measure the objects through a demonstration and explanation from the teacher. For example, sometimes students asked the teacher to show how to classify certain objects. The classifying skill depends on the characters of objects being sorted. Some students can group certain objects more easily than other objects. For example, it easier for young students to classify a collection of buttons rather than a collection of leaves. Thus, to classify a more complex collection of objects, the students need more help from the teacher.

## DISCUSSION and CONCLUSION

This study revealed that science learning through the inquiry-based approach improved science process skills of second graders who were the age within the early childhood. The basic science process skills were increased gradually through the first cycle and the second cycle of the research. The total score of the skills improved as well as the scores for each individual skill such as observing, classifying and measuring. Thus, the results of this study support the previous study conducted in Turkey that an inquiry-based approach improved science process skill of fourth, fifth and sixth grades (Ergül et al., (2011). Similarly, Simsek and Kabapinar's study (2010), showed that fifth grade elementary students' science process skills were enhanced by using the inquiry-based approach.

This action research had been undertaken within two cycles. The school established standards for mastery learning. The minimum criterion for mastery learning was 78. Data showed that only 33 % of students achieved the minimum score in post-test after the first cycle. Therefore it was assumed that the first cycle of the learning was not successful. During the first cycle, students were able to use science process skills, however, they still need the written guidance on the worksheets to follow. They did not use the skills spontaneously, especially in using observation skill. In observing the objects, some students did not use various senses or make quantitative observations. In classification, majority of students were able to find the differences and similarities between the objects. Some students could classify a collection of simple objects such as buttons. However, they were not able to do the classification of certain objects such as a collection of leaves. Therefore, they needed more practicing classification skill for various objects. These might be the reasons for the low achievement for some students' science process skills during the first cycle. For all of the science process skills, the majority of students did not meet the minimum standard for the passing criterion of the score $\geq$ 78 during the first cycle. Therefore, the action research was continued to the second cycle.

In the second cycle of the research, students continued practicing the skills through the 5E model of inquiry-based approach. After the second cycle of the study, data showed that 93% of the students reached the minimum criteria of the score $\geq$ 78. Therefore, the results showed that the intervention of inquiry-based science learning was successful after the second cycle of the implementation. During the second cycle, the use of detailed worksheets was greatly reduced so the students were able to work more independently. Students practiced observation skill by singing a special song. In the second cycle, the students also practiced doing more classifying. Additionally, they already have got the skill to find the difference and similarities of the objects. Similarly, students practiced measuring and that make them master in applying unit of measurements. There were total 20 lessons in the two cycles of this study. These lessons enabled students to practice basic science process skills regularly. As a result, this study indicated that the second graders need a quite long time to improve the basic science process skills gradually.

This study also revealed how second grade students improve the basic science process skills in science learning through the inquiry-based approach. Students used the skills in the phase of exploration of the inquiry-based model of 5E. They were involved in the exploring science's hands-on activities. Results showed that young students enjoy hands-on activities. According to Çimer, (2007) many researchers suggested that students should be actively involved in the learning activities for effective science learning. Hands-on activities are important during the investigation in inquiry-based learning to improve students' attitude toward science learning (Koç & Böyük, 2012). In this study, planning the investigation and choosing material for hands-on activities were very important factors. This study revealed that investigation types and materials need to be relevant for hands-on activities to develop each aspect of the science process skills. Moreover, the students learned using the skills as a concrete practical experience through scientific investigations. A study by Alkan (2016) showed that experiential learning was effective to enhance academic achievement and scientific process skills.

This study revealed both worksheets and singing the song had an important role in mastering the basic science process skills. In the first cycle, students carried out their investigation by following written instruction on the worksheets. The students were able to follow the instructions on the worksheets as these instructions were provided with simple language and illustrations. During this study, some students seemed to be passively involved in working in their small group. According to Choo, Rotgans, Yew, & Schmidt (2011), passive learners could be depending more on the worksheet to guide them than involved in small group learning opportunities. Although the students learn with guidance using worksheets, students need to be involved in science learning for several lessons. Thus, students practiced applying basic science process skills through regular practices. These practices allowed students to develop their habit of using the science process skills. A study from Turkey by Aktamis and Ergin (2008) used students' worksheets of science process skills to enhance their science achievement.

In the second cycle, the students worked without using the worksheets. A song about observation was provided students to help them using observation skill. They had the opportunity to sing the song when they need. This study indicated that the song also strengthened the manner of the students to use observation skill in science learning through inquiry-based approach. Students seemed to enjoy exploring the objects while they sing to recall the procedures of how to observe appropriately. This result also supports the previous study by Governor, Hall, and Jackson, (2013) that song can be used as a mnemonic device to help students to learn science.

In accordance with the lessons plan, this study applied a structured inquiry-based approach to science learning. However, during the learning process, sometimes the teacher also needed to explain some concepts and demonstrate how to investigate and find the answer. Thus, some students learn through a confirmation level of the inquiry-based approach. According to Rezba, Auldridge, and Rhea (1999), (as cited in Bell et al., 2005), there are four levels of inquiry learning; confirmation, structured inquiry, guided inquiry, and open inquiry. This study revealed second grade elementary students can investigate at the level of structured inquiry. However, in a certain situation, students learned through the level of confirmation of the inquiry-based approach. Thus, the second grade elementary students also learned science process skills through a lower to higher level of inquiry. In addition to the inquiry, the teacher also explained some concepts to help students to understand lessons better. This study indicated that various teaching approaches support to improve the basic science process skills. Although during the study, the learning was implemented mainly through structured inquiry-based approach, the teacher also used other approaches in certain situations. A previous study revealed that the use of various teaching approaches in a single lesson could create more opportunities to develop science process skills (Rauf et al., 2013).

This study proved that science learning through the inquiry-based approach improved the basic science process skills for second graders. The students practiced using basic science process skills mainly through structured inquiry activities of the 5E learning model. The study also showed that some factors considered contributing to the inquiry-based approach in science learning. In addition to hands-on activities, the students employed the basic science process skills by following simple written instruction on the worksheets. The students also used a song as a tool to recall the procedures of observation skill. Student interaction with their teacher and peers were other aspects that affected to improve the science process skills. Various teaching approaches such as demonstration and explanation can also contribute to improving the basic science process skills.

This study can have practical implications for early elementary science teachers. The important implication of this study is a teacher can use an inquiry-based approach to improve basic science process skills for second graders in early elementary school. For students who are usually taught with an expository approach, the teacher can start with a structured inquiry. However, in a certain condition, a confirmation level of inquiry may be also needed. Bell and his colleagues (2005) suggested scaffolding the inquiry gradually from the lower to higher level. This study also had an implication that young students need time to spontaneously apply basic science process skills. The study showed that the majority of young students used mainly the sense of sight during observation. Therefore, hands-on activities should focus on to strengthen other appropriate senses such as smell, touch, sound, and taste when it is possible. Another implication is the teacher can use simple worksheets and a song to promote the basic science process skills for early elementary school students.

**Suggestion**

Science learning through the inquiry-based approach can be applied to the regular program to improve basic science process skills for second graders. This study was limited to the second graders in elementary school. Therefore, similar future studies may also use an inquiry-based approach for first graders or younger children. Since the learning approach used in this research was mainly the structured inquiry of the 5E model, future studies may employ other levels of inquiry.

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# Moroccan University Students' Conceptions of Neurotransmission

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## ABSTRACT

Neurotransmission represents a key concept in the history of biology. The objective of this study is to elicit Moroccan university students' conceptions of neurotransmission and highlight potential difficulties and obstacles that may hinder its effective learning. A questionnaire was administered to 120 science students as a pre-test. After the neurotransmission course at Dhar El Mahraz Faculty of Science, the same questionnaire was re-administered. The results of the study appeared that the majority of the science students had deficiencies at integrating and assimilating the concept of neurotransmission and other related concepts.

**Keywords:** Conception, nervous message, neurotransmitter, neurotransmission, synapse.

## INTRODUCTION

Neuroscience employs several scientific disciplines to understand the nervous system and its functioning (Clarac & Ternaux, 2008). Even though neuroscience firstly emerged as a branch of biology and medicine, advances in scientific knowledge and methods of the nervous system (biology, biochemistry, pharmacology, anatomy and physiology) has considerably extended its scope.

Nerve physiology, an integral part of neuroscience, includes great technical facilities for further characterized discoveries (Debru, 1999). Nerve physiology also embraces the chemical neurotransmission, which is opposite to theories of electrical and chemical nervous functioning. Hence, it represents a crucial moment in the history of biology to unveil cellular communication and the language of cells (Dupont, 1999). Chemical neurotransmission refers to the passage of nervous message across a synapse that releases a neurotransmitter stored in pre-synaptic vesicles. Specific receptor's synaptic cleft and fixation move from pre-synaptic surface to post-synaptic surface (Loewi, 1935).

Given the importance of the neurotransmission concept in biology (Dupont, 1999). The basic notions were introduced in high schools education through a didactic transposition

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adapted to the cognitive level of pupils. The deepening of these notions continues through the course taught at the second year of university. The aim of this course is to achieve the following goals: (a) to allow students to understand the integrity and identity of an organism that requires its operational modulation and control to ensure intercellular communication and necessary information transfers; (b) to acquire basic notions concerning the physiology of excitable elements and intercellular communication (nerve cells, muscle cells and endocrine cells).

Despite an increase in the importance of neurotransmission content, how to teach and learn it has still been unexplored as compared to other life science topics such as digestion, respiration. Further, students find the neurotransmission difficult and have lower scores at the summative assessments. Moreover, previous researches on teaching and learning neurotransmission state that students possess some conceptual confusions and difficulties (Astolfi, 1992; Darley, 1994; Bec & Favre, 1996; Laribi et al., 2010). Indeed, only one study by Darley (1994) reported that university biology students at the second-year had some confusions at defining term ‘action potential’. Tremendous researchers have focused on students’ conceptions of science concepts and identified factors hindering student learning through didactic strategies (Jonnaert, 1988; Mein, 1988; Mein & Clément, 1988; Clément, 1994; Albanese & Vicentini, 1997; Ozmen, 2004; Kaddari, 2005; Kochkar, 2007; Schneider & Stern, 2010; Abraham, Perez & Price, 2014; Kampourakis, Silveira & Strasser, 2016; Luksa et al., 2016).

It is generally accepted that the conceptions constitute an explanation system permitting learners to interpret various scientific situations. This hypothesis is of interest in the current study. Whose purposes are to elicit Moroccan university students’ conceptions of neurotransmission and highlight potential difficulties and obstacles that may hinder its effective learning. So, the following research questions guide the current study: (1) Do university students have basic knowledge of neurotransmission? (2) Does this course enable them to acquire advanced scientific knowledge?

*Theoretical Framework*

This study relies on the notion of "conception," which is defined as a body of spontaneous knowledge representing the student’s explanatory models and reading schemes of reality **(**Martinand, 2009; Giordan & Martinand, 1988).

Astolfi and Develay (1989) see conceptions as an "existing conceptual framework in mind", while Giordan and Martinand (1988) consider it as a "frame of reference" and/or "preliminary ideas" held by a student. The term "misconception" means a "deviation from scientific knowledge of reference" (Novak, 1984), and/or "false ideas" (Sencar et al., 2001; Gonzalez, 1997; Schmidt, 1997). Indeed, the learner understands the world through his previous experiences/conceptions. Hence, he constitutes an explanation system to read and interpret reality. In this sense, it is commonly accepted that new knowledge interacts with pre-existing one in conceptual framework (Bec & Favre, 1996).

Students’ learning difficulties of biology may result from their pre-conceptions. These pre-conceptions are also a part of mental knowledge systems. They correspond to a working coherent system interpreting scientific phenomena (Jonnaert, 1988). For this reason, conceptions are resistant to conventional teaching and persist throughout schooling (Astolfi & Peterfalvi, 1993). Any learning obstacle/difficulty at higher education may stem from previous schooling years (Darley, 1994). So, the current study claims that if science students have difficulties at acquiring and assimilating biological concepts in higher education, this may come from their conceptions or pre-existing experiences at secondary school classes.

Learning means a transformation of conceptions (conceptual change) to a more advanced and abstract issue/knowledge (Joshua & Dupin, 1999). DiSessa (2002) addresses that this conceptual change moves from a fragmented knowledge to a well-structured one, whilst Vosniadou (2002) views this transformation as an assimilation of new knowledge to the existing structures.

## RESEARCH METHODOLOGY

To test research questions of the study, we followed the subsequent methodology:

I) To determine the content of neurotransmission at the university level, we used the curriculum and course materials written by the teachers. Thereby, they defined scope and content of the concept. Indeed, the nervous communication is a motor command between a nerve cell and a muscular cell. The transmission of the message from one cell to another requires a particular structure, called synapse, and neurophysiological mechanisms involving these synapses and their correspondence to neurotransmission. The neurotransmission concept, which has some roots in the basic sciences, is taught in the second year of the university (Semester 4).

The physiology of nerve and muscle cells course treats neurotransmission through the functional anatomy of the neuromuscular junction or neuromuscular synapse at the base of the motor command. This study focused on the following concepts: neuron, synapse, neurotransmitter and neurotransmission.

II) To overview the university students' "expected" conceptual profiles and estimated there prerequisites of these notions, we examined the syllabus content of high school curriculum dealing with neurotransmission or synaptic transmission. We counted on “life and earth science” textbook used in the first-year of baccalaureate. Thus, we identified such basic concepts as the nature of nervous message, neuron, synapse, and neurotransmitter.

III) Given earlier steps for high school and university students, we developed a questionnaire as a diagnostic tool articulated around the basic fundamental notions of neurotransmission.

This questionnaire comprised of upstream and downstream of neurotransmission teaching. Upstream of neurotransmission embraced students' pre-existing knowledge and prerequisites before learning neurotransmission at the university. Downstream of neurotransmission covered how students evolve their knowledge after the course at the university. Therefore, we estimated whether their performances would have developed.

In fact, the students' conceptual growth may highlight their obstacles and difficulties of the neurotransmission concept.

### a) Description of the questionnaire

The questionnaire consisted of close-ended questions, open-ended questions and schema to a better understanding of the students' conceptions.

- Six close-ended questions (Q1-Q5 and Q7) requested students to choose the appropriate answers in the multiple-choice format, which limits the answer type and facilitates its treatments.
- Two questions (Q6 and Q8) asked students to draw their schemas of the synapse and neuron concepts.
- Two open-ended questions (Q9 and Q10) allowed students to freely answer without any structured format. Hence, we purposed to elicit students' views and varied answers.

Different types of the questions may enable us to check the implications of the subjects and ensure the validity of the questionnaire.

### b) Sampling and conditions of administrating the questionnaire

It was administered to 120 second-year (semester-4) science-major students enrolled to the Life Sciences at Dhar El Mahraz Faculty of Science during the 2015-2016 academic year.

As aforementioned, the questionnaire was administered before and after neurotransmission education. That is, we firstly passed over the questionnaire to the students as a pre-test. Then, after the neurotransmission education (which took about a month and half), we re-administered the questionnaire to them as a post-test in an amphitheater for the same population.

The students anonymously responded the questionnaire about 30-45 minutes; also we informed them that their responses to the questionnaire would not be evaluated for any credit.

### c) Data Analysis

The students' responses to the closed questions were imported into the Excel 2007, while those for the open-ended questions were analyzed by means of the key words. Data from the pre-test and post-test were entered into an Excel spreadsheet and presented within tables and figures through frequencies and percentages.

## RESULTS

To highlight the students' conceptual growth, the percentages of their answers to the pre-test and post-test were reported in the same histogram.

### a) The propagation of nervous message

Their responses to question 1 (Q1), on the upstream phase of the neurotransmission education which is about the propagation of nervous message (see Figure 1), showed that 72% of the students depicted that the nervous message spread continuously, while 28% of them said that the nervous message progressed through a discontinuous manner.

As seen from Figure 1, the downstream phase of the neurotransmission education revealed a small variation for the data obtained. 38% of the students selected the correct choice (the nervous message propagates through a discontinuous manner), whilst 62% of them marked that the spread of nervous message was continuous. This showed that even after an extensive teaching, the majority of students tended to represent a continuous nervous message.

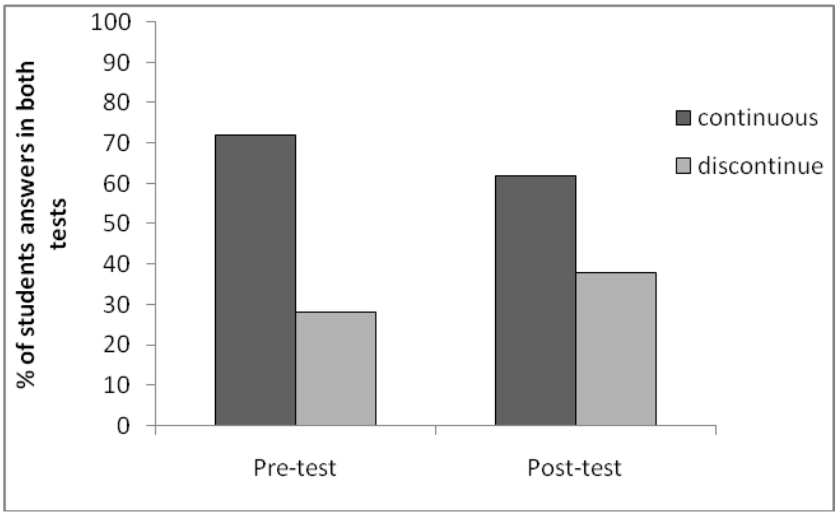


***Figure 1.*** Percentages of the students' answers to the propagation of nervous message.

**b) The nature of the nervous message**

Their responses to the question 2 (Q2) (which focuses on the nature of the nervous message) pointed that only 33% of them chose the correct one (the nerve message is both electrical and chemical in nature) for the pre-test. On the other hand, two-third of them marked the wrong answers (the nervous message is only electrical in nature for 42% of students; and the nervous message is chemical in nature for 25% of students).

Those findings do not seem to improve after the neurotransmission course (see Figure 2). In fact, half of students implied that the nervous message was electrical in nature, whereas 23% of them stated that the nervous message was chemical in nature. 27% of the students understood the nature of the nervous message (chemical and electrical).

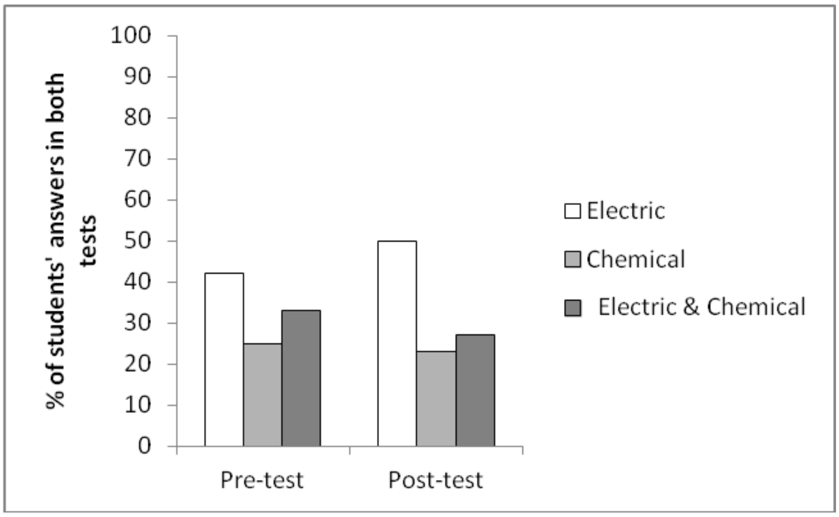


***Figure 2.*** Percentages of the students' answers to the nature of the nervous message.

**c) The responsible structure for the transmission of nervous message**

Their responses to question 3 (Q3) (determining the responsible structure for the transmission of the nervous message (neuron, synapse or axon) showed that 76% of students selected the correct choice (the synapse is the responsible structure for the transmission of nervous message) for the pre-test. Further, 24% of them marked incorrect ones (the transmission is done by the neuron for 12% of students; and it is by the axon for 12% of them) (see Figure 3).

As can be seen from Figure 3, the downstream phase of the neurotransmission education indicated no change in the students’ answers. In other words, majority of them (74%) chose the correct answer, while some of them (26%) marked the incorrect answers.

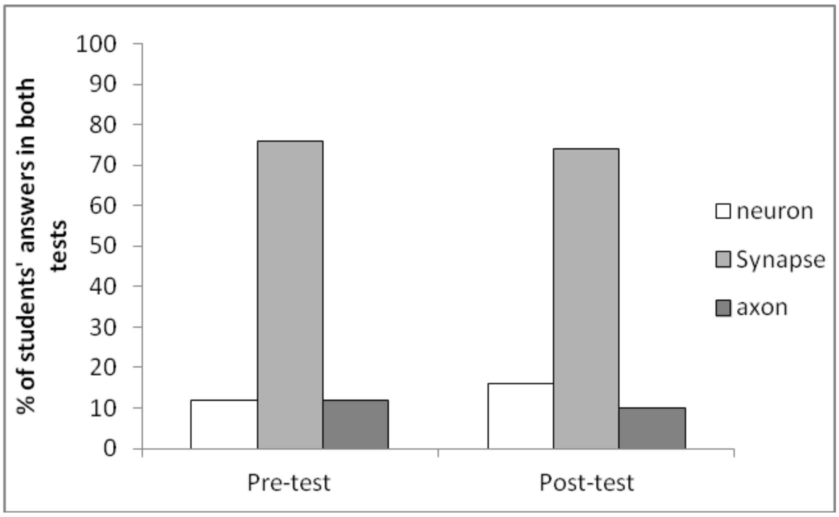


***Figure 3***. Percentages of the students’ answers to the responsible structure for nervous message transmission.

### d) The synapse definition

The students responses to question 4 (Q4) (which is about the definition of the synapse) upstream the teaching of neurotransmission concept, showed that 52% of them chose the correct definition of the synapse ((a) Contact area specialized in the transmission of nerve messages). Further, 48% of them marked the incorrect synapse definitions ((b) pre- and post-synaptic elements forms synapse, or synapse designates the space between the pre-and post-synaptic elements (c)). As seen from Figure 4, the downstream phase of the neurotransmission education showed that the percentages of the incorrect answers slightly increased (61%). Their responses to the pre- and post-tests revealed that more than half of them were unable to exactly define the synapse concept.

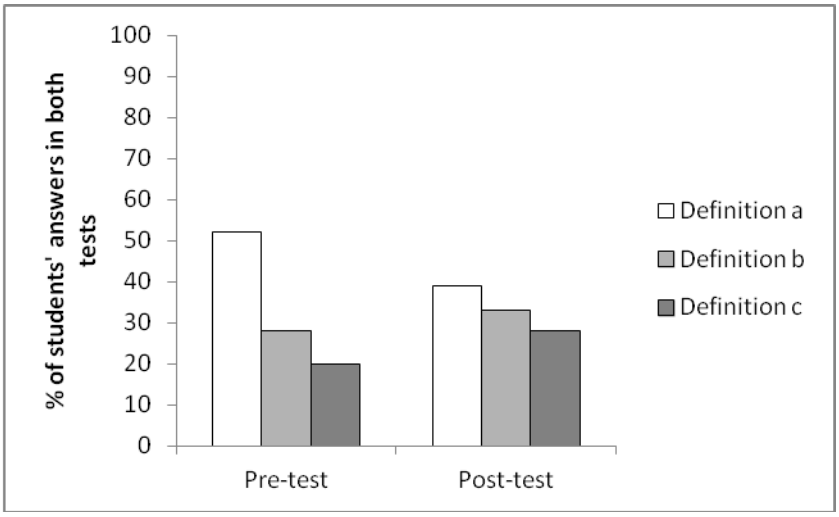


***Figure 4.*** Percentages of the students’ answers to the synapse definition.

**g) The number of functional type of the synapse**

Given their responses to question 5 (Q5) (which is about the type number of the synapse) on the upstream phase of the neurotransmission education showed that 40% of students correctly answered two functional types of synapse. In contrast, 60% of them selected incorrect answers (three functional types of synapse--47%; and five functional synapse types--13%) (see Figure 5). Downstream of this teaching, majority (61%) of students tended to mark incorrect answers (three functional synapse types--51%; and five functional synapse types--10%). Further, 39% of them correctly answered the question 5. These results showed that most of the students did not master the number of the synapse concept.

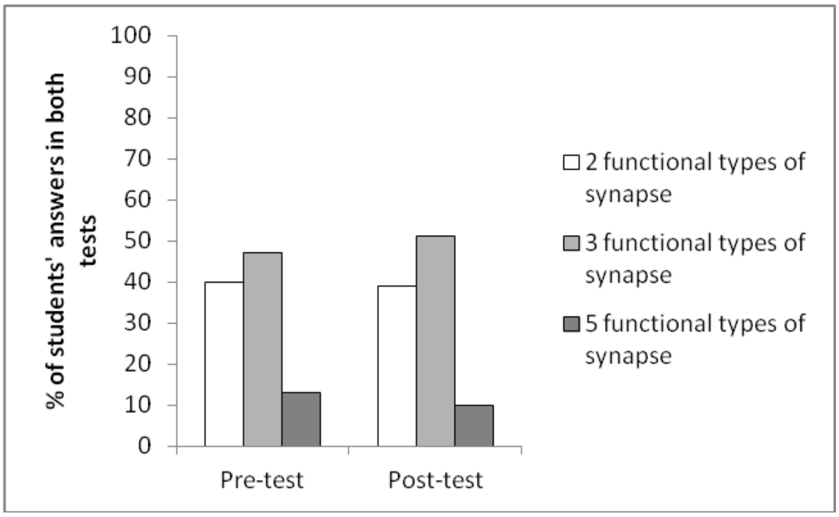


***Figure 5.*** Percentages of the students' answers to the functional type number of the synapse.

**h) The synapse pattern**

For the question 6 (Q6) we asked the students to make a synapse pattern. Their responses to the pre- and post-tests indicated that over 90% of them could not give a correct pattern for the synapse (see Figure 6). That is, these students seem to have found the iconic issues problematic.

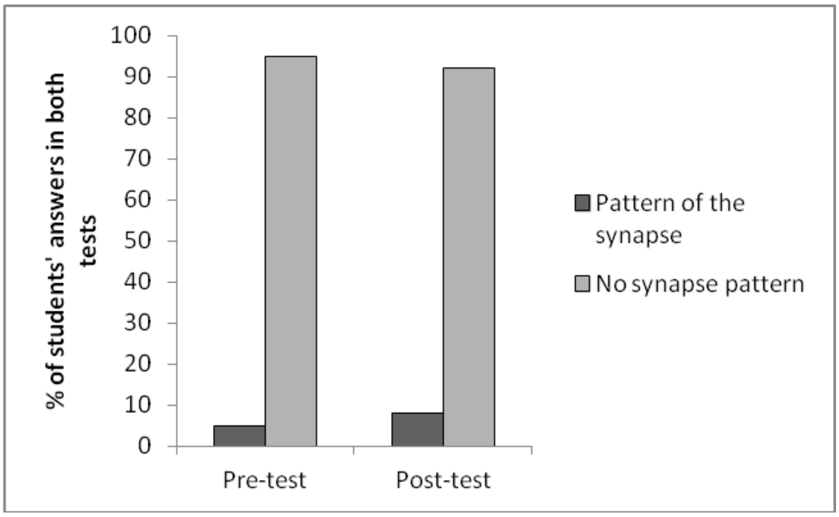


***Figure 6.*** Percentages of the students' answers to the synapse pattern.

**ı) The definition of the neuron**

The question 7 (Q7) involves the neuron concept, which is a key concept of neurotransmission. The results showed that the students perceived the neuron as an uncontrolled concept. In the pre-test, only 21% of them referred to two correct definitions (a+c) namely that: (a) the neuron is a nerve cell composed of a nucleus surrounded by structures in the form of stars (dendrites) and a long prolongation (axon) and (c) endowed with specific properties which are excitability, propagation and transmission of nervous message. On the other hand, 53% of them chose one of the correct definitions. In fact, 43% of them limited their responses to an anatomical description of the neuron (definition a), whilst only 10% of them dealt with the functionalities of the neuron (definition c). The rest of them (26%) marked the incorrect definition (the neuron is the only cell that constitutes our brain--definition b).

The results of the post-test revealed an increase in the percentages of the correct answers (see Figure 7). But this increase was not enough, since the percentages of the students, who gave the correct definition of the neuron (definitions a+c), did not exceed 32%. Indeed, two-third of them did not fully understand the concept of neuron. The fact that half of them opted one correct definition (definitions a or c) means that their answers still remained incomplete. Also, the fact that 18% of them selected the incorrect definition (definition b) showed that these students were unable to achieve a level of conceptualization allowing them to acquire the neuron concept.

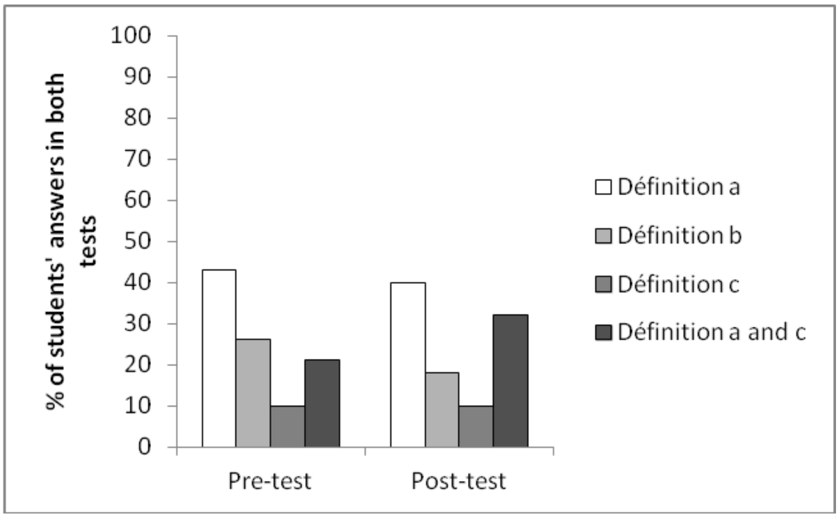


***Figure 7.*** Percentages of the students' answers to the neuron definition.

**i) The neuron pattern**

As seen from Figure 8, their responses to the question 8 (Q8) which is about the neuron pattern) showed that the students did not really conceptualize the neuron concept. The percentages of the students, who were unable to give the neuron pattern, were 69 for the pre-test and 82 for the post-test.

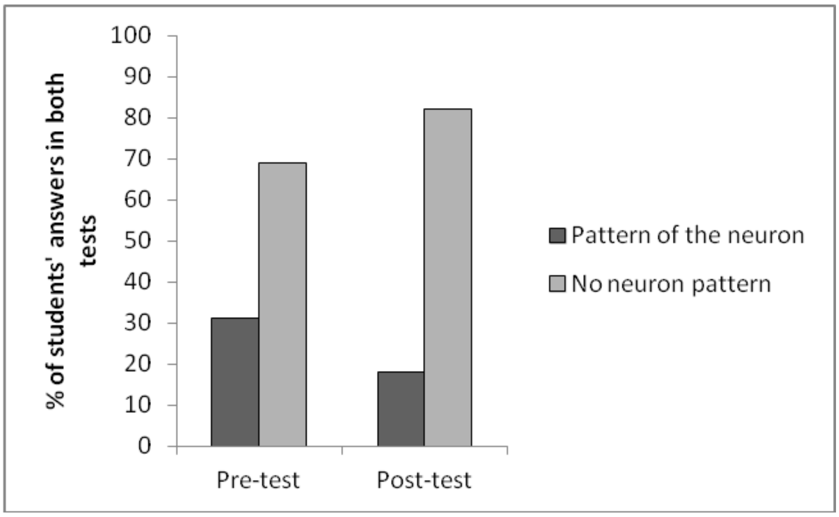


***Figure 8.*** Percentages of the students' answers to the neuron pattern.

**j) The definition of the neurotransmitter**

The question 9 (Q9), which is an open-ended question, students were asked to define the concept of the neurotransmitter. To analyze their responses to the question 9, we based on identified a set of key words defining the concept of the neurotransmitter (chemical substance, transmits the information, synthesized by a neuron).

As observed in Figure 9, the results obtained on the upstream phase of the neurotransmission education indicated that 52% of the students did not propose any definition for the concept of the neurotransmitter. Further, 12% of them seemed to confuse the neurotransmitter with the neuron (i.e., the neurotransmitter is a neuron). Moreover, the percentage of the students, who formulated a correct definition, was 36%. This percentage was divided into two students categories which 8% of them defined the neurotransmitter or neuromediator as a chemical substance synthesized by a neuron in a synapse and transmits the information (nervous message) from a neuron to a cell target. Moreover, 28% of the students formulated some partial definitions, which were more or less correct with incomplete definition of the neurotransmitter concept. The percentages of some fragmented definitions, which included chemical substance, chemical substance synthesized by a neuron, information transmission from one neuron to another and cited neurotransmitters such as GABA, Acetylcholine or a neuromediator are 8%, 5%, 9% and 3% respectively.

For the same question, the downstream phase results of the neurotransmission education were almost similar to the upstream ones. Indeed, 65% of the students were unable to give a definition for the neurotransmitter, whereas 12% of them gave incorrect definitions (the neurotransmitter is a neuron--7%; and the neurotransmitter acts as a synapse--5%). As well as, the percentage of the students, who gave correct and complete answers, was about 23.

As can be seen from Figure 9, majority of the students did not assimilate the neurotransmitter concept and their conceptual growth of the concept was very minimal.

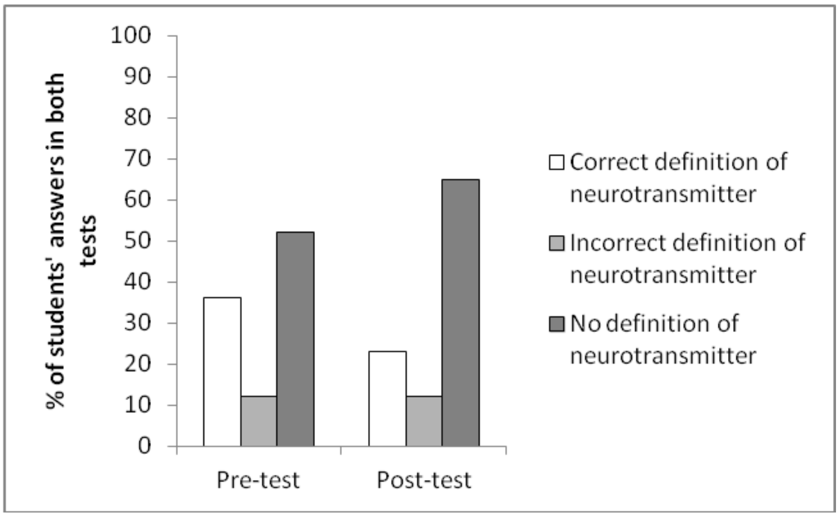


***Figure 9***. Percentages of the students' answers to the neurotransmitter definition

**k) The definition of the neurotransmission concept**

The question 10 (Q10), students were asked to define the neurotransmission concept. As seen from Figure 10, most of the students (78%) in the pre-test did not give a definition for the concept, whilst 13% of them gave an incorrect definition of the concept (defining the concept as a synapse--6%; and receiving it as a nervous message--7%). In contrast, 9% of them were able to give a correct definition of the neurotransmission concept. That is, the correct definition refers to the passage of nervous message across a synapse, which releases a neurotransmitter stored in pre-synaptic vesicles into the synaptic cleft. Thus, specific receptors present its fixation from pre-synaptic surface into post-synaptic surface.

As observed in Figure 10, 83% of the students did not define the neurotransmission concept in the post-test. 7% of them answered that the neurotransmission was a transformation of the nervous message, which is an incorrect definition. On the contrary, 10% of them were able to give the correct definition of the neurotransmission concept.

The results of their responses to the question pointed that majority of the students did not fully comprehend the neurotransmission concept after the neurotransmission education at the university.

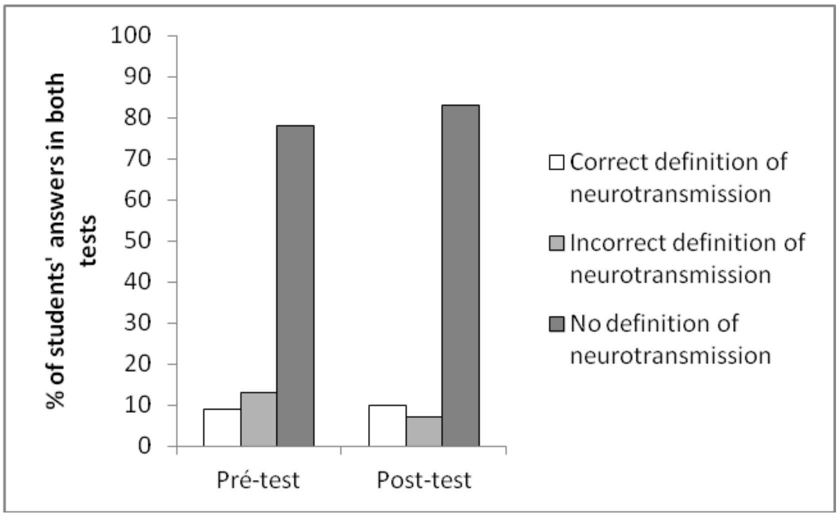


***Figure 10.*** Percentages of the students' answers to the neurotransmission definition

## DISCUSSION

The students' responses to the pre-test and post-test showed that most of the students perceived the propagation of the nervous message as a continuous (Q1) (72% in the pre-test and 62% in the post-test). Moreover, nearly half of them viewed it as an electrical nature (Q2) (42% in the pre-test and 50% in the post-test). The results highlighted the persistence of the electrical conception and its pre-acquired resistance. This may stem from the electrical model of the nervous message, which is the most detailed and treated in high school. Hence, the students seem to have not gone beyond this model. In spite of an advanced teaching on the concept, the students tended to base on their pre-conceptions of the concept treated in the high school (1st year of the Baccalaureate of Earth and Life Sciences). This result is in a harmony with Laribi et al. (2010)'s statement on the dominant feature of the electrical conception in transmitting the nervous message among students.

Their responses to the question (Q3) showed that three-quarter of the students seemed to understand the responsible structure of the nervous message transmission, namely the synapse. Furthermore, their responses to the questions (Q4, Q5 and Q7) indicated that, most of the students had deficiencies at well-assimilating two concepts (synapse and neuron) despite the fact that they had a deeper education at the university. This result is consistent with a study on the nervous system conducted by Bec and Favre (1996), who showed that the Biology course has a limited effect on the appropriation of concepts by the pupils of the final year of higher school. Also, the results of their responses to the questions 6 and 8 (Q6 and Q8) revealed that the students possessed some pitfalls at visualizing the concepts "synapse and neuron." This finding is in a harmony with Kaddari's (2005) study highlighting university students' perceptual difficulties of the atomistic iconic.

The results of the students' responses to the two open-ended questions 9 and 10 (Q9-Q10) indicated that most of the students failed to integrate chemical conception into learning of the neurotransmission concept. To define the concepts "neurotransmitter and neurotransmission," the results showed the persistence of the electrical conception.

The students' answers to the questionnaire clearly illuminated a consistency throughout all questions because majority of them asserted that the nervous message propagated within a continuous manner. This means that those students prefer using the electrical conception instead of involving the chemical one. On the other hand, this may be due to the fragmented learning way that makes these students fail to link the introduced concepts with each other (Laribi et al., 2010). This finding is in a parallel with confirmed by Sadi (2014) depicting that the students perceive genetics as a separate learning area and memorize the concepts, terms and definitions without any interlink between them. Nevertheless, the complexity of scientific knowledge (Astolfi, 1992) (e.g., the concepts "neurotransmitter and neurotransmission") may make student learning difficult.

These difficulties may hinder their learning of the neurotransmission concept and prevent their conceptual evolution/progression to build an adequate knowledge close to scientific reality. In fact, this result is very consistent with earlier studies. That is, they have reported that students' knowledge is often overestimated (Kaddari, 2005; Ozmen, 2004; Clément, 1994; Albanese & Vicentini, 1997) and pre-conceptions sometimes constitute barriers/obstacles to learning (Jonnaert, 1988; Darley, 1994; Schneider and Stern, 2010; Abraham, Perez & Price, 2014; Kampourakis, Silveira & Strasser, 2016; Luksa et al., 2016). So, it can be deduced that the students have difficulties at differentiating their conceptions from related scientific knowledge (Laribi et al., 2010). Phrased differently, it can be inferred that they pay little attention to restructuring their conceptual understanding/worldviews into a more sophisticated model (Morin, 2014).

## CONCLUSION

The results of the present study show that the students' notions of the neurotransmission concept are very primitive and far from mastery. As a matter of fact, students are mostly unable to assimilate their pre-conceptions to their learning processes. Indeed, such factors as, the persistence of pre-conceptions, the dominance of misconceptions and the limited effect of the learning sequence may block their conceptual growth to properly acquire the neurotransmission concept. Furthermore, the fact that the students possessed difficulties at schematizing the related concepts reveals that the Life Sciences students' iconic competencies are poor.

The similarity between the students' pre-conceptions of the neurotransmission concept should be integrated into further learning/understanding and instructional designs. These results call further studies for explaining the origins of the related learning difficulties and obstacles. Hence, future studies should determine pedagogical tools allowing university students to acquire the neurotransmission concept. Some of these pedagogical tools are of interest in ongoing studies/projects.

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# The Effect of Integration of STEM Disciplines into Toulmin's Argumentation Model on Students' Academic Achievement, Reflective Thinking, and Psychomotor Skills*

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## ABSTRACT

The aim of this research was to examine the effect of integration of STEM disciplines into Toulmin's argumentation model on students' academic achievement, reflective thinking, and psychomotor skills. To be able to get this aim, a quasi-experimental method was used. The participants were 40 sixth grade middle school students divided into two groups, an experimental and a control group with 20 students in each group. The students were at the same achievement level and in a similar socioeconomic status in a public middle school. The experimental group received the treatment in the while the control group received traditional learning of the same topic. The data were collected from academic achievement test, reflective thinking test, and psychomotor observation form. The collected data were analyzed by using Mann Whitney U-test, descriptive analyses (e.g., percentage and frequency), and correlation analyses (Pearson's product moment). According to the data obtained from the measurement tools, it was detected that the integration of STEM disciplines into Toulmin's argumentation model can be used for enhancing the academic achievement of students. It was specified that reflective thinking tendency levels of the experimental group were found to be at a high level. It was also documented that psychomotor skills of experimental group were found to be at a high level. The results suggested that the integration of STEM disciplines into Toulmin's argumentation model can be used for increasing academic achievement of students, developing of the reflective thinking, and observing the development of psychomotor skills at the formation of arguments in the classrooms.

**Keywords:** Toulmin's argumentation model, STEM education, academic achievement, reflective thinking, psychomotor skills.

## INTRODUCTION

The discipline of science aims to make individuals develop the awareness of sustainable improvement pertaining to society, economy, and natural resources. The aims also include making individuals recognize the mutual interaction between environment and

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society. To do so, students should be able to make arguments and questions by taking advantage of different disciplines, make claims from these arguments, and also corrupt opponent claims (Hasançebi, 2014; Ministry of National Education [MoNE], 2013b). In order to achieve this goal, it is expected that students should be capable of creating their own arguments effectively by using disciplines such as science, technology, engineering, and mathematics in their daily life (Boran, 2014; Yaman, 2003).

The idea of the argumentation started with Stephen E. Toulmin (1958) in the literature. Toulmin created arguments and logic for the arguments on the philosophy of discussion as seen in Table 1 (Simon, Erduran, & Osborne, 2006; Tümay, & Köseoğlu, 2011). The questions in Table 1 give an idea about how teachers can plan their lessons according to the argumentation model, and in what situations teachers can follow students or in what situations teachers can guide students. Students can use the questions in constructing research inquiry activities and as an assistive framework in writing research reports (Günel, Kabataş Memiş, & Büyükkasap, 2010; Verheij, 2005). Examining a problem with questions is the aim of the argumentation model (Gülen, 2016). The fact that the problem is solved in the context of evidence according to the argumentation model and the evidence is scientifically characterized by the disciplines of science, technology, engineering, and mathematics (STEM) to ensure that students can use more effective expressions in their daily life (Ata Aktürk, Demircan, Şenyurt, & Çetin, 2017; Drew, 2011; Dunne, Hunter, McBurney, Parsons, & Wooldridge, 2011).

STEM is an educational approach that has emerged as a result of societal needs with increasing economic developments and scientific studies (Aydeniz, Çakmakçı, Çavaş, Özdemir, Akgündüz, Çorlu, & Öner, 2015; National Receivers Council (NRC), 2015; Sanchez, Wells, & Attridge, 2009). The primary objectives of STEM education are (a) having a qualified workforce, (b) adopting STEM disciplines and gender equality, (c) ensuring individuals constituting the society to have the 21st century skills. In addition to creative, critical, reflective thinking, increasing literacy in all areas are known as the skills of the 21st century with such learning skills as being able to make arguments (Carnevale, Smith,& Melton, 2011; Century Skills, 2010; Ceylan, 2014;KabataşMemiş, & Ezberci Çevik, 2018; Gülen, 2016).

**Table 1.** *Questions inviting teachers-students in argumentation model*

| Step | Teacher | Student | Purpose |
|---|---|---|---|
| 1 | What is the preliminary information? | What are my questions? | Identifying the problem |
| 2 | Ready for the activities? | What can I do? | Collecting data (possible solutions) |
| 3 | Does he/she participate in the activities? | What have I observed? | |
| 4 | Is he/she claim? | What can I claim? | Optimal solution proposal |
| 5 | Can he/she defend his claim? | What evidence do I use? | Test |
| 6 | Can he/she compare it? | What are the opposite claims? | |
| 7 | Can he/she compromise? | What has changed? | Contact |
| 8 | Can his/her information be configured? | What did I learn? | |

Currently, the aims of STEM education are being applied at the level of middle school, primary school, and even kindergarten. Integration is the most important point planned to be implemented in schools in the STEM education approach (DeChenne, Koziol, Needham, & Enochs, 2015; Torres & Cristancho, 2018).

**Table 2.***The Approaches to be used/used in STEM education*

| Order | Engineering Design Process | Design Based Science Education | Probing Based Learning | 5E Model | Argumentation model |
|---|---|---|---|---|---|
| 1 | Problem determination | Great design task | Problem identification | Engagement | Identifying the problem |
| 2 | Possible solutions | Mini research | Identification of sources | Exploration | Possible solutions |
| 3 | Choosing the right solution | Design solution | Possible solutions | Explanation | Optimal solution proposal |
| 4 | Making prototype | Construction of the design | Analyzing the solutions | Elaboration | Test |
| 5 | Test | Testing, communication | Submission of the solution | Evaluation | Contact |

Researchers have indicated that it is not true to adhere to a certain approach in the program integration of STEM education (Altun & Yıldırım, 2015; Honey, Pearson, & Schweingruder, 2014). Table 2 shows the approaches with their properties that have been used for the integration. When the common characteristics of these approaches are considered and Table 2 is examined, it is considered that the Toulmin's argumentation model can be used besides these approaches.

As stated in Table 2, one of the primary objectives of STEM education is to "solve real life problems." Individuals may have different approaches to solve real life problems (Altun & Yıldırım, 2015; MoNE, 2016). In a scientific process, a student can identify a problem, propose possible solutions, and find more than one solution in the light of evidence that problem (Gülen, 2016). By getting the necessary resources, the student collects and specifies the most appropriate solution. When the desired success is achieved, the student makes announcements about the achievement, presents it, and communicates with society. When the phrases to solving the problem of approaches in Table 2are integrated into STEM education, integrated STEM education around four disciplines, interdisciplinary or disciplinary occurs with behaviors and considerations of student, teacher or teacher connections in a secondary school program (Bozkurt, 2014; Ercan, 2014). This situation suggests that Toulmin's argumentation model can be used to integrate STEM education into the program of secondary school (Gülen, 2016).

Furthermore, students can solve the problems of daily life by using integrated STEM approach and Toulmin's argumentation model approach so that they can solve the problems by using claims, negotiation, and evidence (Ulu & Bayram, 2015). In STEM education, the solution of the problems occurs through different disciplines until finding the most appropriate solution. As in the Toulmin's argumentation model, the importance of evidence for problem solving in STEM education is fairly considerable (Corlu, 2013; Demircioğlu & Uçar, 2014; Fairweather, 2008). For this research study, a lesson plan was prepared at the secondary school level by using disciplines of STEM. The lesson plan is based on the Toulmin's argumentation model with integrated STEM education.

There are many studies on STEM education and argumentation in the related literature. However, there have been limited studies on the integration of STEM disciplines into Toulmin's argumentation model. In this study, researchers investigated the effects of the integration of STEM disciplines into Toulmin's argumentation model on students' academic achievement, reflective thinking, and psychomotor skills. Academic achievement is defined as the acquisition of the targeted achievements during the learning process and the representation of these achievements with symbolic values (Korkmaz & Kaptan, 2002). Reflective thinking skills are the process of thinking to reveal positive or negative aspects of teaching or learning in problem solving (Ersozlu & Kazu, 2011). Psychomotor skills are in parallel with the physical growth and development of the central nervous system that reflects how the organism gains mobility depending on the demands. It is a process involving the acquisition of the skills that start in the prenatal period and continue until death (MoNE, 2013a; Özer & Özer, 2014).In this study, the following research question was taken into consideration: What is the level of impact of the integration of STEM disciplines into Toulmin's argumentation model on students' academic achievement, reflective thinking, and psychomotor skills?

*Purpose of the research*

The purpose of the research was to examine the effect of the integration of STEM disciplines into Toulmin's argumentation model on students' academic achievement, reflective thinking, and psychomotor skills. In doing so, a lesson plan on the conduction subject of electricity in the sixth-grade science of middle school was prepared.

*Problems of Research*

1. Was there a statistically significant difference between the academic achievement of experimental group and control group before and after the study?
2. What were the levels of the reflective thinking and psychomotor development of the experimental group?

## METHOD

In this research, a quasi-experimental design was used. The quasi-experimental design is a method used to measure variables and control cause-effect relationships among the variables (Büyüköztürk, 2014). In the study, the progress of students' academic achievement was investigated in both experimental and control groups while the development of reflective thinking and psychomotor skills were only examined in the experimental group so that the analyses were performed on a single group (i.e., experimental group) to determine variables of reflective thinking and psychomotor skills.

### a) Participants

The study group of this research was selected via the appropriate sampling method. The participants were 40 students originating from two groups as experimental and control groups. The research was conducted in a middle school with sixth grade students in an urban province of Turkey. Students' socioeconomic levels were similar.

### b) Unit design and procedure

*Lesson plan*: The following lesson plan of this study was created by Selvi et al. (2015) in the structure of seven-steps plan (i.e., subject, problem, achievement, process, method, test, and evaluation) of Altun and Yıldırım (2015).
*Subject*: The topic of Transmission of Electricity was selected from the sixth grade of the science curriculum.
*Problem*: Prepared according to the integration of STEM disciplines into Toulmin's argumentation model and included problems from daily life.

*Gain*: It consists of five gains in the curriculum on Transmission of Electricity topic.
*Procedure*: It is planned to be implemented using the integration of STEM disciplines into Toulmin's argumentation model. The following model was derived from the argumentation model of Toulmin (1958) and the integration of the STEM approach. In this model, students can collect data in a sample case and design with their tools using the data. They can determine the positive and negative aspects of the reasons for their claims when they formulate the claims and transact on the designs. They can transform their designs into products by using their tools in the last stage (Kabatas Memiş, 2011; Gülen, 2016).

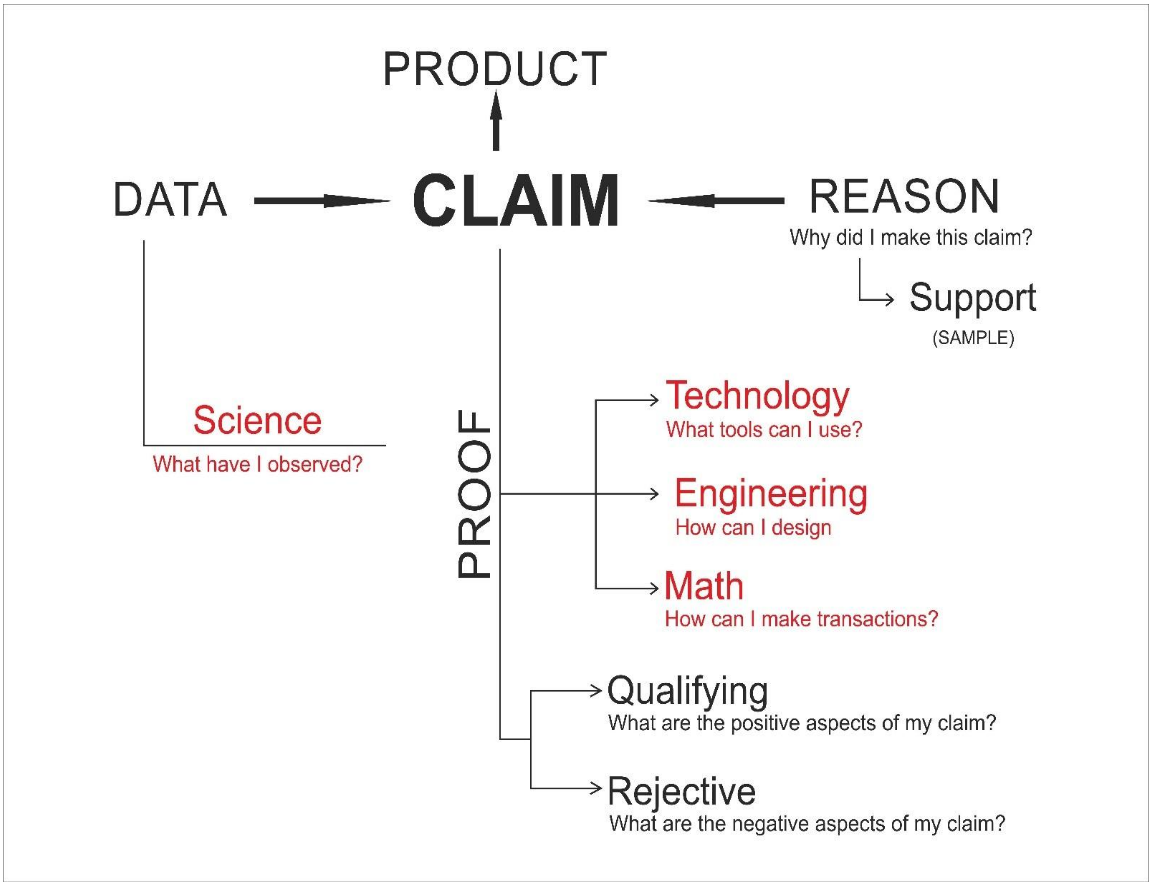


***Figure 1.*** Integration of STEM disciplines into Toulmin's argumentation model in science education

In figure 1 model;

Claim: Opinions or explanations for the solution of the problem.
Data: Events or observations used to support the claim.
Rationale: These are the reasons why the data support the claim.
Support: Examples are given daily.
Qualifier: Conditions that the claim is valid.
Rejection: Conditions that the claim is invalid.
Technology: It is the equipment used in the product to be built.
Engineering: Design of the product to be built and planning with existing technology.
Mathematics: Processes to solve the problem through the product.
Product: It is the concrete model that students use engineering and mathematics with technology.
Science: Container concept covering every step described above (Ceylan, 2012; Günel, Kıngır, & Geban, 2012).

*Methodology*: It provides a groundwork for students' use of STEM disciplines in activities involving daily life problems. The proposed solution needs to be negotiated among the groups

in the prepared activities. The results should be modeled using tools that are brought to the classroom by the researcher.
*Test*: It is the step that the products prepared by the students are tested for the solution of the problems.
*Assessment*: The stage in which the process and result are evaluated.

### c) Data Collection

*Academic achievement test*: After the examination of the sixth-grade science program (MoNE, 2013b), an academic achievement test consisting of 68 questions (multiple choices) was prepared. The expert opinion was received for the reliability and validity of the achievement test. The questions with low substance discrimination index were removed after receiving the idea of expert and analysis results in the pilot application and the number of items was reduced to 24. The validity and reliability of the academic achievement test were also taken into consideration. The content validity was censured by thinking of the achievement of the unit, preparing each issue at the appropriate level. Scores of the academic achievement test used as a predictive variable for students' unit success. Structure, appearance, and criterion validity of the academic achievement test was also considered. At the result of reliability calculation, KR20 reliability coefficient was calculated as 0.87. According to this result, it can be said that the test of academic achievement gives reliable results (Büyüköztürk, 2009).
*Reflective thinking scale*: A scale measuring reflective thinking ability of students in solving problems related to conduction issue of electricity topic created by Kızılkaya and Aşkar (2009) was used. The reflective thinking scale is composed of 14 items including questioning, evaluation, and causing dimensions. Confirmatory factor analysis was carried out using SPSS and AMOS programs to make these items suitable for research. When the obtained data analyzed, it was seen that the indices of compliance were in the "acceptable level" (Gülen, 2016).

**Table 3.** *Calculated compliance indexes results of confirmatory factor analysis*

| Compliance index | Accepted value | Observed value |
|---|---|---|
| Kay-square/Degree of freedom | <2.00 | 1.67 |
| GFI | >0.90 | 0.92 |
| NFI | >0.90 | 0.80 |
| CFI | >0.90 | 0.90 |
| RMSEA | <0.10 | 0.06 |

*Observation form of psychomotor skills*: It is important that the information structured in STEM education can be used in the applications of real life (Bicer et al., 2015). Due to this importance, the psychomotor skills of students need to be determined in order to specify the extent to the fact that the information, configured with the usage of the integration of STEM disciplines into Toulmin's argumentation model in the study, can be applied in the real life applications. In the literature review, it was found that the psychomotor skills include six steps. The steps are perception, establishment, guidance, convert to fool, and conditioning. These steps were compared with the achievement test results of the Electricity Conduction unit, and except for the last step, it was found that the achievement levels were sufficient for all steps (Tutkun, Demirtas, Erdoğan, & Arslan, 2015). Thus, the form was prepared and applied with appropriate criteria for the research. Two experts in science education assisted the preparation process of the achievement test.

### d) Data Analysis

All data from the academic achievement test (Mann-Whitney U-test, percent (%), frequency (f)) were analyzed with the SPSS package program. Additionally, the factor analysis of the reflective thinking test was done with the AMOS package program. Reliability and validity analyses of the academic achievement test, reflective thinking test, and observation form of psychomotor skills were done with the support of Microsoft Office Excel package program. The observation forms of psychomotor skills and reflective thinking test were analyzed by using descriptive statistical techniques.

The scores obtained from the variability of the academic achievement test, the reflective thinking test, and the psychomotor skills observation forms were varied. Therefore, all scores were converted to standardized scores (Z scores) to be able to analyze the relationships among scores obtained from the different tests. Pearson's correlation coefficient was calculated to determine the relationship among these scores (Büyüköztürk, Çokluk, & Köklü, 2013; Can, 2014; Güler, 2011).

### e) Limitations of the study

This study was limited to the 20 students in the experimental group and 20 students in the control group. Only academic achievement test, reflective thinking, and psychomotor skills developments were observed in the study. Also reflective thinking and psychomotor skills development were limited to the experimental group.

## RESULTS

The results of the analysis relating to the variability obtained in the survey are presented in the following section. The results are presented in the order of research problems.

**Table 4**. *Mann Whitney U test of experimental and control groups according to pre-post test results of academic achievement test*

| Tests | Groups | N | Order average | Rank Sum | U | p |
|---|---|---|---|---|---|---|
| Pre test | Control Groups | 20 | 23.75 | 475 | 135 | 0.077 |
| | Experimental Groups | 20 | 17.25 | 345 | | |
| Post test | Control Groups | 20 | 16.50 | 330 | 120 | 0.029 |
| | Experimental Groups | 20 | 24.50 | 490 | | |

As shown in Table 4, the value of "p" was calculated as 0.077 ($p > 0.05$) while the average value of pre-test *U* was 135 before the application. These findings indicate that there was no significant difference between the two groups before the application. However, the average value *U* of the post-test was 120 after the application, meaning that there was a significant difference between the two groups after the application. The values of rank average indicate that the difference was in favor of the experimental group.

**Table 5.** *Descriptive statistical values according to reflective thinking dimensions of experiment group*

| Factors | Items | $\bar{X}$ | Factor $\bar{X}$ | S |
|---|---|---|---|---|
| Questioning | 1 | 3.50 | 3.36 | 1.05 |
| | 3 | 3.45 | | 0.82 |
| | 7 | 3.15 | | 0.93 |
| | 9 | 3.35 | | 0.90 |
| | 13 | 3.35 | | 1.13 |
| Evaluation | 2 | 3.35 | 3.67 | 1.13 |
| | 4 | 3.60 | | 1.04 |
| | 6 | 3.70 | | 0.80 |
| | 10 | 4.15 | | 0.93 |
| | 14 | 3.55 | | 0.99 |
| Cause | 5 | 4.05 | 3.67 | 0.88 |
| | 8 | 3.55 | | 1.05 |
| | 11 | 3.30 | | 1.17 |
| | 12 | 3.75 | | 0.78 |
| General average | | | 3.56 | |

According to Table 5, the experimental group's average scores obtained in the dimensions of evaluation and causation was 3.67. These scores suggest that the experimental group's showed "medium tendency of reflective thinking in the evaluation and reasoning dimension." However, the average level of inclination toward the test was specified to be 3.56. This value shows a high reflective thinking tendency according to Kandemir (2015) criteria.

**Table 6.** *Descriptive statistical values of psychomotor skills according to Bloom levels of experiment group*

| Steps | Items | $\bar{X}$ | Factor $\bar{X}$ | S |
|---|---|---|---|---|
| Perception | 1 | 4.60 | 4.62 | 0.68 |
| | 2 | 4.60 | | 0.68 |
| | 3 | 4.65 | | 0.59 |
| Establishment | 4 | 4.65 | 4.60 | 0.67 |
| | 5 | 4.55 | | 0.83 |
| Guidance | 6 | 4.50 | 4.50 | 0.69 |
| | 7 | 4.35 | | 0.67 |
| | 8 | 4.65 | | 0.49 |
| Convert to fool | 9 | 4.10 | 4.03 | 0.85 |
| | 10 | 4.05 | | 0.83 |
| | 11 | 4.00 | | 0.79 |
| | 12 | 4.00 | | 0.79 |
| | 13 | 4.05 | | 0.76 |
| | 14 | 4.00 | | 0.79 |
| Conditioning | 15 | 3.80 | 3.80 | 0.77 |
| | 16 | 3.80 | | 0.77 |
| | General average | | 4,30 | |

According to the results of Bloom levels of descriptive statistical values to the psychomotor skills of the experimental group, as seen in Table6, the psychomotor skills of experimental group were 4.62 at the level of perception, 4.50 at the level of guidance, 4.60 at the level of establishment, 4.03 at the level of conversion to ability, and 3.80 at the level of suitability to situation. It was indicated the general average of the psychomotor skill levels of the experimental group were 4.30.

**DISCUSSION**

It was determined that the experimental group, who were taught with the integration of STEM disciplines into Toulmin's argumentation model, had statistically significant higher scores than the control group, who were taught with traditional teaching approach, in the post academic achievement test. There are studies in the related literature demonstrating that the argument-based science learning (ABSL) approach improves the academic success of the students and that the results of the previous related studies are parallel with the results of this study. Researchers such as Altun (2010), Ceylan (2012), Gultepe and Kilic (2015), Günel, Kabataş Memiş, and Büyükkasap (2010), and Uluay (2012) comparing the traditional education approach with the ABSL approach indicated that the ABSL approach is more effective than the traditional method in increasing students' academic achievement. In the study of Okumuş (2012), which compared the current teaching program with the ABSL approach, it is stated that the ABSL approach increases the academic achievement of the students. It was determined that the ABSL approach is more effective in increasing academic achievement in the studies of Koçak (2014) and Demircioğlu (2011),which compared the ABSL approach with the traditional approach. However, Deveci (2009) found that there was no significant difference between the experimental and control groups although the academic achievement level of the experimental and one of the control groups differed significantly in a three-group study. In addition, Demirel (2015) who compared the current curriculum with the ABSL approach found that the ABSL approach has a similar effect with the traditional methods in increasing the academic achievement. The researchers of Ercan (2014) and Ceylan (2014) conducted some of the earliest studies about the impact of the STEM educational approach on the academic success of the students in the national literature. Ceylan (2014) compared the constructivist approach supported by existing science curriculum based teaching practices with the STEM educational approach in his research study and revealed that the STEM educational approach increased the academic achievement of students. Ercan (2014) noted that classroom activities with the STEM approach improved the academic achievement. Additionally, in the studies of Yıldırım and Altun (2015) and Marulcu and Mercan Höbek (2014), it was found that STEM education and practices of engineering increased students' academic achievement. Fortus, Dershimer, Krajcik, Marx, and Mamlok-Naaman (2004) and Fortus, Krajcik, Dershimer, Marx and Mamlok-Naaman (2005) documented that the academic achievement of the students increased in the STEM studies. The results of the impact of STEM education on the academic achievement in the studies and results of the impact of the integration of STEM education in this study on the academic achievement are similar. Apart from these findings, no study was found on the integration of STEM disciplines into Toulmin's argumentation model.

In the result of the integration of STEM disciplines into Toulmin's argumentation model, it was determined that the average of the reflective thinking skills of the experimental group was 3.56 and this value was "high" within the criteria developed by Kandemir (2015).It was detected that the majority of researches aimed at determining the measurement and development of reflective thinking skills of pre-service teachers. In a research study by Duban and Yanpar Yelken (2010), they demonstrated reflective thinking tendencies of the pre-service teachers and overlapping tendencies with teacher qualities. Özden, Karapınar, and Önder (2015) documented that classroom pre-service teachers' usage of reflective thinking significantly reduced. In Lee's (2005) study, it was specified that the development in the reflective thinking skills of the pre-service teachers is dependent on the contextualization level of their readiness, communication, dialogue making ability, questioning ability. It was found that the level of reflective thinking was high in the study of Kaf Hasircı and Sadık (2011). These results are similar to the results of this research. In their studies, Demirel, Derman, and Karagedik (2015) were specified that there was a moderate relationship between students' reflective thinking levels and problem solving abilities. Scardamalia, Bereiter, and Steinbach (1984) pointed out that students' ability to make loudly speech and ask questions about his/her own thought enhance reflective thinking. In his study, Farewell was indicated that being capable of thinking of what individual learns influence the reflective thinking. There is evidence that the interaction of students in the process of argumentation influences reflective thinking. Erbil and Kocabaş (2015) reported that an activity of collaborative learning positively affected the reflective thinking skills of primary school students. Demiralp and Kuzu (2012) claimed that when teachers use the environment of interactive learning in their classes, students take positive results in the development of reflective thinking skills. These results can suggest that interactions and collaboration among students contribute to developing reflective thinking skills in the activities of integration of STEM disciplines into Toulmin's argumentation model.

Furthermore, the students' scores in this study decreased from high-level to low-level demonstrated that the development of the students' psychomotor skill was in high-level in the activities of classroom based integration of STEM disciplines into Toulmin's argumentation model. Atlı (2007) found that the activities performed in the classroom consisted of a meaningful change in the students' psychomotor skills. Doydu (2012), Ulutaş (2011), and Yüksel (2010) stated that the activities made by the students improved the psychomotor skills. In addition, Türkçapar (2011) specifies that the level of psychomotor skills also increased with the increase in students' cognitive achievement levels. These findings show that students actively participated in the learning environment with the integration of STEM disciplines into Toulmin's argumentation model, met with ease at strutting of their knowledge so that the integration of STEM disciplines into Toulmin's argumentation model effected on the development of the students' psychomotor skills. In contrast to these results, it was found that there was no relationship between the activities performed in the class and the development of students' psychomotor skills in the studies by Kuru, and Köksalan (2012) and Ural (2015).

## CONCLUSION and SUGGESTION

From the result of the academic achievement test, it can be said that the integration of STEM disciplines into Toulmin's argumentation activities applied in the experimental group increased the academic success of the student according to the current curriculum applied in the control group.

From the result of the reflective thinking test, it can be said that the reflective thinking tendency levels of the experimental group were in "the tendencies of highly reflective thinking." Furthermore, it was found that the students had a tendency of "moderate reflective thinking tendencies" in the questioning dimension, "high reflective thinking tendency" in the dimension of questioning, and "highly reflective thinking tendency'' in the dimension of evaluation and reasoning. Based on the post-test results, it can be said that high level thinking skills of students developed with the integration of STEM disciplines into Toulmin's argumentation model.

Although there was a decrease in the average scores of high-level steps of the psychomotor skill level of the students in the experiment group, it can be said that it was considerably high when the general average was examined. These results suggest that the integration of STEM disciplines into Toulmin's argumentation model had a high impact on the development of students' psychomotor skills. In addition, when we look at the correlations among the variables obtained in the result of the research, it can be said that the relationships among the students' psychomotor skills, academic achievement, and reflective thinking ability were at a high level. In the light of results obtained in the study the integration of STEM disciplines into Toulmin's argumentation can be used in increasing students' academic achievement.

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# The Effects of *Science-On-Web* Learning Media on Junior High School Students' Learning Independency Levels and Learning Outcomes

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## ABSTRACT

This research aimed to examine the effects of science-on-web learning media on grade 8 students' learning independency levels and learning outcomes of 'excretion system' topic. Through a quasi-experimental research method within non-equivalent control group design, 70 grade 8 students drawn from Tanjungpinang, Indonesia participated in the study. Pretest and posttest were carried out before and after the teaching intervention. Two intact groups were assigned as the experimental and control classes (35 by 35). The experimental class was exposed to the science-on-web learning media, while the control one was instructed through the electronic module. Data were collected through a learning independency observation sheet and a learning outcomes test. This research showed that the experimental class significantly performed better at learning independency levels and learning outcomes than the control one.

**Keywords**: Learning independency, learning media, learning outcomes, science-on-web.

## INTRODUCTION

Information and communication technology (ICT) has dramatically been improving in this globalized era. ICT aspects include such digital media tools as computer, laptop, internet and smartphone. Computer and internet contribute a great educational advantage to learning. Thus, teacher should encourage students to utilize computer and internet as important tools to support education, improve knowledge, broaden the opportunities and empower a better qualified life.

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Schools, as social institutions, play an important role in changing people's lives. Hence, schools purpose to equip students with challenging any rapid change. That is, ICT facilities in schools enable students to actively and independently achieve learning. Further, teachers need to have these skills to improve and use learning media. Arsyad (2014) and Sadiman et al. (2017) state that media, which acts as a tool to deliver learning messages from sender to receiver, stimulates student's mind, emotion, attention and passion to the learning process. These experts' arguments imply that using the appropriate learning media affords students to build a better understanding of science and triggers their learning motivation to achieve learning goals.

One of the learning media is computer-based-multimedia that Indonesian in junior high school students are familiar with. While choosing appropriate learning media, students' characteristics, learning trends and challenges should be taken into consideration. For example; an audio visual media on website, which is accessible at any time by using computer, laptop, notebook or smartphone, meets their characteristics. In view of Rusman (2013), the object and interactive-computer-based media are the best resources for communication purposes/needs. These types of learning not only focus on media or objects, but also encourage students to actively interact with the media or peers.

Yen, Tuan, & Liao (2011), who conducted a web-based research, found that web-based learning made a significantly higher contribution to learning outcomes and assisted students in accomplishing a better understanding of the topic. Similarly, Shih et al. (2010) depicted that web-based learning media gave an opportunity for students to improve student's knowledge and self-regulated learning. Therefore, it is believed that the use of *science-on-web* learning media in form of HTML may create a funny and interesting learning environment for classical or individual (independent) learning.

The 'Excretion System' topic has its own characteristics in that it links structural, functional, procedural features of daily live to health of kidney, liver, lung and skin. The excretion system is an intangible topic to help students visualize and understand it via an interesting learning media. Web-based science learning media (science-on-web) has a potential to enable them to visualize the excretion concept.

As a new learning environment, web users can design and use web pages to get any help and information on the Internet. For instance; some students use websites to visualize any phenomenon or example (Donovan & Nakhleh, 2001). Therefore, web pages can be used to attain learning processes.

HTML (Hyper Text Markup Language), which is a programming language to create web pages, contains easy accessible information for people (Curran Bond, & Fisher, 2012). The newest HTML version is HTML5 that many browsers in computer and mobile devices have supported (Baker, 2014; Chen et al., 2013). HTML5 contains texts, static graphics and dynamic graphics (e.g., animation), hyper textual and graphical links. HTML5 can also be inserted within other programming languages (e.g., Java script, Java and CSS3) to design more interactive web pages (Garaizar, Vadillo & López-De-Ipiña. 2014; Sikos, 2011).

HTML5, which has an advantage not to need a special compiler, such as Fortran and Delphi, simply calls such browsers as Google Chrome, Mozilla Firefox and Microsoft Internet Explorer. Also, HTML5 particularly does not need an external plug-in program ( i.e., Adobe Flash) to display audio and video contents (Curran et al. 2012; Lubbers et al., 2011). In other word, HTML5 has been designed as an independent device.

Shih et al. (2010) describe self-regulated learning as a four-attribute learning process:

*(1) Intrinsically or self-motivated: Self-regulated learners tend to maintain learning behavior with a very strong motivation. Learners can raise this motivation through some practices, such as setting learning goals.*

(2) *Planned or automatized: Self-regulated learners are apt to use some strategies along with their learning processes, including both cognitive and self-regulated strategies. Generally, learners improve their learning performance when using self-regulated strategies rather than cognitive strategies. Self-regulated strategies contain goal-setting, goal-planning, organization, transition, exercise, and so on. A self-regulated learner needs to effectively use self-regulated strategies for his/her learning.*

(3) *Self-aware of performance outcomes: Throughout the learning process, self-regulated learners sharpen their self-awareness of learning behaviors. To approach an ideal outcome, self-regulated learners should be aware of their own learning qualities, and change their behaviors or strategies correspondingly.*

(4) *Environmentally/socially sensitive and resourceful: The learning environment(s) and resources affect one's learning pattern. Self-regulated learners have better skills in seeking learning resources or support. With such ability, they should arrange the environmental conditions and search for other resources effectively (p. 87).*

Benson & Voller (1997) state that self-regulated learning fully depends on student’s own performances (e.g., learning and applying skills; practicing individual responsibility as an outcome of self-regulated learning; and determining their own learning paths).

Learning independence, as a learning process, affords students to plan, monitor and manage their own learning (Marini & Boruchovitch, 2014). Tsai, Hsu, & Tseng (2013) state that self-regulated learning, which refers to metacognitive, motivation and behavior processes, enables students to focus on and control their own learning. Metacognitive process includes managing and designing learning, while motivation process incorporates self-evaluation. Further, behavior process contains to choose, set up and create the best learning environment(Wan, Compeau, & Haggerty, 2012). Moreover, a self-regulated learning activity connects learning environment to learning outcomes (Pintrich & Zusho, 2002; Schunk, 2005). Motivation, as an important aspect of self-regulated learning, will trigger student’s learning enthusiasism (Bharathi, 2014; Marini & Boruchovitch, 2014; Zimmerman, 2008). Overall, learning independence, as a self-regulated learning activity, not only makes students responsible for their learning processes but also possesses their own study initiatives, self-confidence and a high learning motivation.

The European Union (EU) (2015) implies that learning outcomes mean student’s competency/achievement level via measurement and assessment. Learning outcomes includes such statements as what a learner knows, understands and does during a learning process. Kennedy, Hyland, & Ryan (2006) describe learning outcomes as a student’s mastery level at learning process.

UNESCO (2015) sees learning outcomes as students’ educational knowledge, attitudes, values, and skills. This means that learning includes three main learning domains (i.e., cognitive, affective, and behavior) (Grabau & Ma, 2017; Økland, 2012).

A learning outcome consists of students’ learning efforts/performances (i.e., doing, knowing and understanding the targeted issues) in the end of learning period (Brooks et al., 2014). In a similar vein, Adam and Expert (2008) claim that students will gain some knowledge after their involvement with learning process. Hamalik (2011) considers a learning outcome as a learning achievement indicating student’s behavioral change. This research aimed to examine the effects of science-on-web learning media on grade 8 students’ learning independency levels and learning outcomes of in the ‘excretion system’ topic. Because science on-web learning media visualizes the concept of excretion, it supports student learning independency. Students can use science-on-web learning media via the guide instructions existing on the media independently. In brief, this study hypothesized that science-on-web learning media would increase grade 8 students' learning independency levels and learning outcomes.

## METHODS

Through a quasi-experimental method within nonequivalent control-group design, pre-test and post-test were carried out before and after the teaching intervention (see Table 1).

**Table 1**. *An outline of the quasi experimental research design*

| Group | Pretest | Treatment | Posttest |
|---|---|---|---|
| Experimental | T1 | X1 | T2 |
| Control | T1 | X2 | T2 |

T1: Pre-test, T2: Post-test, X1: Science-on-web learning media, X2: Electronic module learning media

The use of science-on-web, which was offline, and CD format for enriched materials, enabled students to independently play at anytime and anywhere. The science-on-web, which was developed via HTML5, included animations and other visualization objects for the 'excretion system' topic. The electronic module learning media involved power points, videos and multimedia.

The sample of the research comprised of 70 grade 8 students drawn from a Junior High School 5 in the state of Tanjungpinang, Indonesia. Two intact groups were assigned as the experimental (17 boys and 18 girls in class VIII E) and control (15 boys and 20 girls in class VIII D).

### a) Data Collection Instruments

To collect data, a learning independence observation sheet and a multiple-choice test were exploited. The learning independence observation sheet was used to measure students' learning independence levels, while the objective test was employed to measure their learning outcomes.

### b) Learning Independence Observation Sheet

Content and construct validity of a 4-point learning independence observation sheet was ensured by an expert. There were five observed aspects, i.e., responsibility, learning initiative, dependence on other people, self-confidence and learning motivation. These aspects reflecting learning independence were converted into 11 indicators.

### c) Multiple-Choice Test

A 30-item multiple choice test was administered as a pre-test and post-test. An expert, whose research interests covered excretion system topic, construction, language and culture, validated the test. The test was pilot-tested with 35 junior high school students, who had already learnt about the topic under investigation. The results of Pearson Product Moment Correlation ($r_{xy}$) were compared with *r product moment* ($r_{tab}$) value. If $r_{xy}$ is larger than $r_{tab,}$ a significant correlation emerges and makes the item valid. That is, 22 out of 30 items were valid since $r_{xy}$ value was larger than $r_{tab}$, i.e. $r_{xy} > 0.339$. The reliability of learning outcome items was measured using Kuder-Richardson's formulae, named α-20's coefficient (Mardapi, 2008). Reliability value was found to be 0.788 meaning a high reliability.

### d) Data Analysis

The students' learning outcome scores to pre-test and post-test were analyzed through gain standard. Meanwhile, their learning independence scores to every observation sheet were also analyzed by using gain standard. Improvement criteria of normalized gain scores are summarized in Table 2 (Hake, 1998).

**Table 2**. *Improvement criteria of normalized gain score*

| No | Normalized Gain Score | Criteria |
|---|---|---|
| 1 | $g \geq 0.70$ | High |
| 2 | $0.70 > g \geq 0.30$ | Intermediate |
| 3 | $g < 0.30$ | Low |

After meeting prerequisite tests, i.e. normality test and similarity of variant covariant matrices test, effectiveness of science-on-web learning media was tested through *One-way* Manova Hoteling's $T^2$. Hypothesis of the current study were as follows:

- $H_0$ : There is no statistically significant difference between mean scores of the experimental (science-on-web learning media) and control (electronic module media) groups' learning independency levels and learning outcomes.
- $H_a$ : There is a statistically significant difference between mean scores of the experimental (science-on-web learning media) and control (electronic module media) groups' learning independency levels and learning outcomes.

## FINDINGS

Multivariate normality test indicated a statistically significant value between the experiment and the control class ($p < 0.05$). This means that the data were distributed multivariate normally. The variant covariant matrices similarity test showed a statistically significant value of 0.193, which was higher than 0.05. This depicts that the experimental and control groups' variant covariant matrices were the same.

After fulfilling the prerequisite tests, i.e., multivariate normality test and homogeneity test, Manova test were performed by using SPSS 23™. The results of hypothetical Manova test are outlined in Table 3.

**Table 3**. *The results of hypothetical Manova test*

| Effect | Value | Sig. | Conclusion |
|---|---|---|---|
| Hotelling's Trace | 0.119 | 0.023 | $H_o$ rejected |

### a) An Improvement in Student's Learning Independency

Two observers observed every lesson by help of the learning independency observation sheet. Any improvement in student's learning independency level was determined their scores to three lessons. Hence, their gain values were calculated to make a comparison. The results of learning independency levels are presented in Table 4.

**Table 4**. *Mean scores of student's learning independency levels*

| Class | Average Value Lesson | | | *Gain* |
|---|---|---|---|---|
| | 1 | 2 | 3 | |
| Experimental | 67.50 | 75.49 | 79.94 | 0,37 |
| Control | 62.56 | 69.71 | 73.54 | 0,29 |

**b) An Improvement in Student's Learning Outcomes**

The students' learning outcome scores to pre-test and post-test are displayed in Table 5.

**Table 5**. *Mean scores of the experimental and control groups' learning outcome scores to pretest and posttest*

| Class | Average Value | | <*g*> |
|---|---|---|---|
| | Pretest | Posttest | |
| Experimental | 42.8 | 80.5 | 0.66 |
| Control | 41.5 | 76.4 | 0.59 |

## DISCUSSION and CONCLUSION

As seen from Table 3, because the significance value was less than 0.05, i.e., 0.023, $H_o$ was rejected, indicating significant difference of learning independency levels and learning outcomes between the experimental and control groups. This means that science-on-web learning media effectively improved the students' learning independency levels and learning outcomes. This result is in a harmony with previous studies indicating that web-based learning improves learning independence (Shih et al., 2010) and learning outcomes (Yen et al 2010). Similarly, Chang (2005), who implemented web-based learning, found that the web-based learning developed the students' learning independence in terms of responsibility and confidence. Chang (2005) also addressed that web-based learning helped them understand the learning material. Robin Kay (2014) also elicited that the students' learning outcomes of natural science lessons significantly increased with web-based learning. This shows that media-assisted learning activities provided opportunities for students to develop knowledge and independent learning. It showed that the students with web-based learning performed better at understanding the related concept than those with direct learning.

As can be seen from Table 4, the experiment group's average values ranged from 67.50 (first lesson) to 79.94 (third lesson). The gain value (0.37) of the experimental group showed an intermediate category. The control group's average values were between 62.56 (first lesson) and 73.54 (third lesson). The gain value (0.29) of the control group revealed a low category. These values showed that the experimental group (science-on-web learning media) had a higher learning independency than that of the control one.

A significant improvement in the experiment al group's learning independency may result from features of science-on-web media (e.g., interesting learning media and new technology). That is, these features may have enhanced their learning interest and motivation. This is in a parallel with the result of Nafidi et al. (2017), who drew out a strong learning motivation as an output of the use of computer simulation. This also means that an advanced technology (i.e., science-on-web learning media) empowers student's self-regulated learning (Winters, Greene, & Costich, 2008) and enables students to have a higher independency level (Wang & Wu, 2008). These findings are also in line with those of Chen (2009), Shih et al. (2010) and Lee & Tsai (2011) reporting that web-based self-regulated learning significantly improved student's self-study capability.

As observed in Table 5, mean scores of the experimental group's learning outcomes were 42.8 in pre-test and 80.5 in post-test. Gain value (0.66) of the experimental group indicated an intermediate category. Meanwhile, mean scores of the control group were 41.5 in pre-test and 76.4 in post-test. Gain value (0.59) revealed an intermediate category. These results showed that the experimental group’s (science-on-web learning media) learning outcomes possessed a better improvement than did the control one.

A better improvement in the experimental group’s learning outcomes of the ‘excretion system’ topic may stem from features of science-on-web learning media (e.g., a clearly interesting visualization of the topic). This is in line with the results of Frailich, Kesner & Hofstein (2007), who found that students with web-based chemistry animation and visualization had a better conceptual understanding than those with regular intervention. Similarly, Kusairi, Alfad & Zulaikah (2016) found that web-based learning media was effective in improving students’ conceptual understanding. In addition, an improvement in students’ learning outcomes is consistent with the results of Kay (2014) reporting that web-based- science learning significantly improved students’ learning outcomes.

The use of technology in class, such as web-based-learning media, provides a proper learning process for students and positively affects their learning outcomes (Zimmerman & Tsikalas, 2005). As a matter of fact, Yektyastuti and Ikhsan (2016) found that using android software media improved students’ cognitive learning outcomes.

The results of the study showed that the value of learning independence had a correlation with learning outcomes. That is, an increase in student learning independence also improved learning outcomes (Zheng, Li, & Chen, 2016). The relationship between learning independency level and learning outcomes supports the results of Uçar and Sungur (2017) addressing that students with a high independency level had good learning outcomes. The results of the current study indicated that science-on-web learning media of the ‘Excretion System’ topic might be used as an alternative approach to improve junior high school students’ independency levels and learning outcomes.

It can be concluded that science-on-web learning media has a potential to improve junior high school students’ learning independency levels and learning outcomes. Thus, the current study recommends that science-on-web learning media be implemented in schools to support their science learning independency and science learning outcomes.

### Suggestions

The availability of wide coverage of internet connection in schools and supporting infrastructures for online learning in Indonesia can assist students to improve their learning independency levels. This fact may contribute to success of education program in 4.0 industrial revolution era in Indonesia. Given the results of the current study. it suggests that science teachers and students should use science-on-web learning media as a medium to accomplish natural science learning. Future studies ought to develop similar science learning media/materials, and integrated into various learning strategies for better learning outcomes.

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# The Development of a Resource Guıde in Assessıng Students’ Scıence Manıpulatıve Skılls at Secondary Schools

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## ABSTRACT

Manipulative skills and abilities include skills in the handling and manipulation of materials and apparatus in the context of scientific investigation. Science teachers appeared to be struggling with the mode of assessment in making authentic evaluation of manipulative skills in laboratories. One of the contributing factors is due to the lack of instrument developed to assess these skills. This paper explains the development of a resource guide in assessing students’ manipulative skills at secondary schools. This study employed a qualitative research methodology. The development of a resource guide in assessing students’ manipulative skills involved three phases; (i) analysis, (ii) design and development, and (iii) implementation and evaluation. The evaluation of this guide was conducted qualitatively with 40 science teachers. Findings showed that the development of this resource guide is advantageous and beneficial to facilitate teachers in determining students’ manipulative skills competency during practical work so that students can be more prepared for the implementation of the upcoming science practical examination. The findings may contribute towards enriching research on assessment of manipulative skills at the secondary school level. Science educators, either pre-service or in-service, may use this resource guide to improve their instruction during practical work.

**Keywords:** Assessment of scientific skills, rubric development, secondary science, practical work, science manipulative skills.

## INTRODUCTION

Science subject requires practical training as well as theoretical studies. Practical work is an essential part of science education and is considered as the most distinctive features of science that can ignite students’ interest. Practical work in this context can be defined as any scientific activity in which learners need to be actively involved, hands-on and minds-on, to observe physical phenomena (Adlim, Nuzulia, & Nurmaliah, 2018; Allen, 2012). The aims of

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the practical work contain developing practical skills that include science manipulative skills. In this study, manipulative skills are psychomotor skills that enable students to use and handle science apparatus and specimens correctly in the approved manner. In schools, these skills are interwoven throughout the science curriculum and include diverse activities in practical laboratory work. Manipulative skills play an important role in science education, especially in higher level sciences, and these skills can only be obtained through ‘hands-on’ practical work. According to past studies, manipulative skills are generally given the least amount of attention in the course of academic instruction even though important aspects of learning can occur in this area (Abrahams, Reiss, & Sharpe, 2013; Ferris & Aziz, 2005; Fuccia, Witteck, Markic, & Eilks, 2012; Fadzil & Saat, 2014; Tesfamariam, Lykknes, & Kvittingen, 2015; Trowbridge, Bybee, & Powell, 2000). Students’ involvement was still low in conducting experiments, and teachers do not effectively guide students (Chua & Karpudewan, 2017; Fadzil & Saat, 2014).

In order for the teaching and learning of manipulative skills to be effective, it is necessary to know what are the criteria to be assessed. One particular feature of the current assessment of manipulative skills in many countries (e.g., Malaysia) is the limited amount of direct assessment of students’ practical skills. Thus, there is less inclination amongst teachers to devote time and effort in developing students’ manipulative skills (Campbell, 2002; Hamza, 2013; Fadzil & Saat, 2014, 2017; Tesfamariam et al., 2015). Furthermore, a study conducted with 40 Grade 6 and Grade 7 science teachers found that teachers still have difficulties in assessing students’ manipulative skills due to the lack of information (Fadzil & Saat, 2014).

The issue of practical work will become more substantial due to the comeback of the practical component of science at a national exam (*Malaysian Certificate of Education)* taken by Grade 11 secondary school students. In this practical exam, students will have to carry out experiments individually based on given instructions, and their marks will be reduced when they receive help from the invigilators. Practical science tests were carried out in the national exam until 1999 when they were replaced by written tests and continuous school-based practical science assessments in Malaysia. The reintroduction of science practical examinations have seen as an appropriate move because studies conducted on the implementation of the continuous school-based practical science assessments (Fadzil & Saat, 2014a, 2014b; Ishak, 2014; Ng, 2014) showed many weaknesses in the program which need to be given more attention. Studies also found that the factors that hinder the effective implementation of the continuous school-based practical science assessments in schools were related to the teachers’ lack of competence and skills in assessment activities (Ishak, 2014; Ng, 2014). Thus, the findings of this study can be significant in providing information on the competency level of students for the implementation of the upcoming science practical examination in Malaysia, and to those nations that have similar interest.

Therefore, the purpose of this research was to develop an instrument, in this case, a resource guide to assess students’ manipulative skills and find out the appropriateness of the instrument from the perspective of experienced science teachers. This research focuses on the following research question: Can the resource guide be used to determine students’ manipulative skills competency during practical work based on the feedback from the experienced science teachers?

## METHODOLOGY

### a) Development of the Resource Guide

This paper discussed the development of a resource guide in assessing secondary school students' manipulative skills during practical work. The rubric developed in this resource guide emerged from the first part of this research, which explored students' manipulative skills in 8 schools in Selangor, Malaysia (Fadzil & Saat,2017). During the data collection phase of the research, laboratory observations of students' practical work were conducted and each student's required four individual experiments were video recorded. The students were also interviewed at least four times. The findings of the previous research showed that the majority of participants responded positively toward the practice of using and handling scientific apparatus in the science laboratory. They were cooperative in every session conducted at primary and secondary schools. However, the majority of students did not display sufficient manipulative skills during the transition from primary to secondary schools. The gap can be detected when students show no progress or even regressed in manipulative skills during the study. The findings from this qualitative research revealed that the main problem arising from the research was that most of the students were unable to master the manipulative skills in using four basic apparatus in the science laboratory, namely the measuring cylinder, thermometer, Bunsen burner, and microscope.

Responses from science teachers from the previous research have prompted a need to prepare some form of guide to be used in assessing students' manipulative skills. Thus, the researchers strongly felt that there was a necessity to prepare this rubric based on the emerging findings in order to facilitate teachers and students in establishing effective manipulative skills. Like with the preparation of any instructional materials, this resource guide was constructed based on the analysis of three instructional design (ID) models. The term ID can be defined as the systematic and organized process for analyzing, designing, developing, evaluating and managing the instructional process efficiently (Dick, Carey, & Carey, 2001; Isman, Abanmy, Hussein, & Al-Saadany, 2012). In this study, three ID models were reviewed for ideas in preparing the materials for the resource guide. The reviewed ID models were the Isman, ADDIE, and ASSURE ID models. From the analysis of the three ID models, the researchers found that ADDIE model serves as a basic framework for most of the design models and it provides an organized way to develop learning activities and instructional programs to ensure competent performance by the learners. Thus, a modified framework of the ADDIE model was implemented in this research, and then the resource guide was revised based on the evaluation process feedback. The three (3) phases of preparing the resource guide are shown in Figure 1.

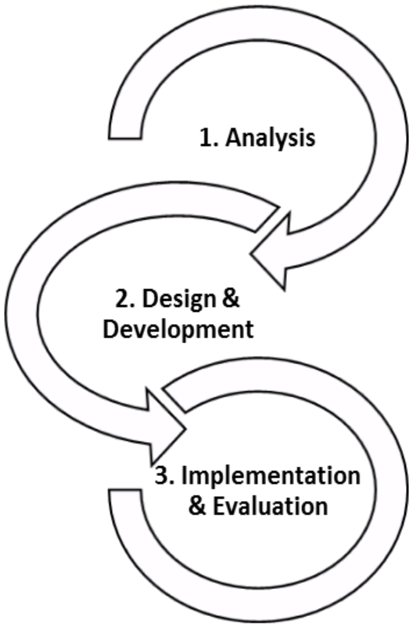


***Figure 1.*** Modified ADDIE model implemented in the development of resource guide

The modified ADDIE model was implemented in developing the resource guide. The involved three phases were (i) analysis, (ii) design and development, and (iii) implementation and evaluation.

*Phase 1: Analysis*

Analysis phase was the pre-planning phase where all the related information for this research was gathered. In this research, a needs analysis was conducted in order to get a comprehensive understanding of the phenomenon. Issues related to the assessment of science manipulative skills were analyzed during the literature review. The information also emerged from the analysis of data from the first part of the research where findings showed that students confronted with difficulties in acquiring manipulative skills (Fadzil & Saat, 2017). From the understanding of the phenomenon, potential solutions for the problem can be identified. Based on the needs analysis, a resource guide was prepared.

*Phase 2: Design and development of resource guide*

The objectives in preparing this resource guide were to provide science teachers with an appropriate method in identifying students' level of competency in manipulative skills and a systematic rubric for the teachers in identifying students' proficiency in manipulative skills. The analysis phase indicated that there is a need to gauge the students' level of competency so that once the students' competency is determined, teachers can enhance their manipulative skills accordingly.

The resource guide has been prepared in the Malay language because the Malay language is the medium of instruction in teaching and learning of science at most of the secondary schools in Malaysia. The resource guide comprised of three main parts, which were (i) diagnostic tests, (ii) manipulative skills rubric, and (iii) description of competency level in manipulative skills. The diagnostic tests served as an instrument for systematic identification of students' problems in manipulative skills. Four activities were proposed (see Table 1). Activity A involved the use of measuring the cylinder, the thermometer, and the Bunsen burner. Activity B involved the use of a microscope, which included the preparation of slide. The apparatuses were chosen from the analysis of the related documents including the science practical textbooks, science curriculum specification, science textbooks, and science teaching and learning materials in secondary schools. The information such as learning objectives, learning outcomes, apparatus, and materials needed for the experiment, experiment procedures, and table for results were provided in the activity sheet for each diagnostic test.

For example, in Task 1, students were required to conduct an experiment to understand how the presence of salts affects the boiling point of water. The learning outcome was to measure the water temperature when impurity such as salt was added to the solution. Students' skills in using the measuring cylinder, the thermometer, and the Bunsen burner can be observed during the execution of this experiment. The apparatus and materials needed for the experiment were beakers, thermometers, Bunsen burners, measuring cylinders, tripod stands, spatulas, glass rods, lighters, candles, tongs, distilled water, and salt. A guide depicting simple procedures of the experiment for students to follow were provided. The students had to write their results in the given space and state the safety procedures they used for this experiment.

**Table 1.** *Activities for the diagnostic test*

| Activity | Learning Outcome |
|---|---|
| Activity A:<br>Understanding water | Activity 1: To measure the temperature of the water when it is heated<br>Activity 2: To understand how the presence of salts affects the boiling point of water |
| Activity B:<br>Science under the microscope | Activity 3: To observe the movement of microorganisms<br>Activity 4: To understand that organisms are built from the basic units of life |

The second section consists of an analysis of the manipulative skills rubric. As mentioned earlier, the criteria and categories in the rubric were based on the findings of the first part of this study which explored students' manipulative skills in using and handling scientific apparatus during the activities (Fadzil & Saat, 2017). The main categories include (a) systematic operation of a task, (b) management of time and workspace, (c) safety and precautionary measures, (d) numeracy, (e) scientific drawing, (f) technical skills in using measurement of the cylinder, thermometer, Bunsen burner, and microscope, as well as (g) the slide preparation for a specimen. There were two rubrics provided in this resource guide: rubric for Activity A and Activity B. During the execution of Activity A and B, teachers were required to observe the students' ability and give points for each criterion: low = 0 mark, intermediate = 1 mark, and high = 2 marks. The total score will reflect a student's ability in manipulative skills for each category. Table 2 summarizes the criteria for the categories in rubric A and rubric B.

**Table 2.** *Criteria for the categories in rubric A and rubric B*

| Category | Criteria |
|---|---|
| A. Systematic operation of tasks | 1. Following instructions in performing an overall operation of a task<br>2. Checking the functionality of apparatus<br>3. Communication with group members to ensure a systematic operation of a task |
| B. Management of time and workplace | 1. Using time<br>2. Condition of the working area before, during, and after the |

| | |
|---|---|
| | experiment<br>3. Cleaning and storing of apparatus and materials |
| C. Safety and precautionary | 1. Safety procedure during the experiment<br>2. The technique in using apparatus in order to prevent unwanted damage |
| D. Numeracy | 1. Making assumptions<br>2. Skill in reading meniscus of measuring the cylinder<br>3. Skill in reading meniscus of the thermometer |
| E. Scientific drawing | 1. Use a pencil to draw<br>2. Production of neat line drawing<br>3. Appropriate title of the drawing<br>4. Correct label of scientific drawings<br>5. Magnification of drawing is indicated<br>6. Authentic drawing – based on observation |
| F. Technical skills in using apparatus | (i) The use of measuring cylinder to measure the volume<br>1. Ability to recognize apparatus, their features, and functions<br>2. Using appropriate measuring cylinder in measuring the volume of solution<br>3. Placement of measuring the cylinder<br>4. Eye position when reading the meniscus<br>5. Efficiency in measuring the cylinder<br>6. The need for guidance<br>(ii) The use of the thermometer to measure temperature<br>1. Ability to recognize apparatus, their features, and functions<br>2. The technique in holding the thermometer<br>3. Using the correct part of the thermometer to measure temperature<br>4. Ensuring the thermometer bulb does not touch the bottom or the wall of the beaker<br>5. Waiting for the temperature to be stable by stirring the solution before taking the temperature<br>6. Eye position when reading the meniscus<br>7. The appropriate way of taking the measurement of the water temperature (did not take the thermometer out from the solution)<br>8. Efficiency in using the thermometer<br>9. The need for guidance<br>(iii) The use of the Bunsen burner<br>1. Ability to recognize apparatus and their functions<br>2. Ability to identify parts and features of apparatus and their functions<br>3. Manipulation of the gas hole before lighting the Bunsen burner (the collar of the Bunsen burner should be turned so that the air-hole can be closed)<br>4. Light up the candle/lighter before turning on the gas<br>5. Manipulation of air hole after lighting up the Bunsen burner (Open the air-hole, so that the flame changes to the non-luminous blue flame)<br>6. Efficiency in using the Bunsen burner<br>7. The need for guidance |

| | |
|---|---|
| | (iv) Slide preparation<br>1. The use of correct stain in an appropriate amount<br>2. The technique in using the slide cover<br>(v) The use of the microscope<br>1. Ability to recognize apparatus and their functions<br>2. Ability to identify parts and features of apparatus and their functions<br>3. Handling the microscope (techniques in holding it and placing on a flat surface)<br>4. The use of stage clips to secure the specimen slide<br>5. The use of the lowest magnification power objective lens by rotating the nosepiece<br>6. Ability to coordinate the mirror, condenser, and diaphragm in order to get a sufficient source of light.<br>7. Adjustment of the coarse adjustment knob until the specimen is in focus.<br>8. Adjustment of the fine adjustment knob until the focused specimen is well-defined.<br>9. Efficiency in using the microscope<br>10. The need for guidance |

Each of the criteria was divided into three main levels (i.e., low, intermediate, and high) of acquisition. For example, the first criteria in category A, “Systematic operation of tasks” is on student ability to follow the instruction in performing an overall operation of a task. When a student is unable to follow overall instructions and the given procedures for the experiment, the student should be considered in the “low” level of acquisition. If a student can follow the instruction and procedures but not as effective as a student in the “high” level, the student should receive the “intermediate” level. Teachers must determine the students’ level of acquisition for each of the criteria in this category and give the appropriate points: “0 mark” for students with a low level of acquisition, “1 mark” for intermediate, and “2 marks” for students in the high level. This procedure needs to be followed by the second category of “Management of time and workspace.”

The cumulative score for each category will determine students’ level of competency. This score can provide a guide for teachers in determining students’ ability in every category of manipulative skills. For example, Student A scores a cumulative of 1 mark in the first category, systematic operation of tasks. From the score guide, under this first category, “0-1 marks” is categorized as “basic level” competency, “2-4 marks” as “intermediate level” competency, and “5-6 marks” as “high level” competency. Student A can be categorized under the “basic” level of competency for this particular category. However, in using the thermometer the student may score 16 out of 18 marks which is categorized under the “high level” of acquisition of skills. From this information, student A’s secondary school teacher should acknowledge Student A’s difficulty in performing the systematic operation of tasks and can continue to improve the student’s skills in this specific category. In using the thermometer, Student A can be considered as proficient, but the teacher can analyze the criterion as there is a possibility that Student A did not stir the solution using the glass rod. From the score, the teacher can determine the student level of competency for each category and summarize the student’s level of competency.

The third section of this resource guide contains a description of each level of competency of manipulative skills. The guide describes the general criteria of a student with “low,” “intermediate,” or “high” competency of manipulative skills. It was constructed based on the research findings and the theories underpinning this research. For example, students with a high level of competency of manipulative skills demonstrate smoothness and efficiency in manipulative skills, display high skills to achieve the learning objectives and can adapt their skills to new situations. The skills can also be applied with minimum supervision. At this level, the movement is ingrained to the students' minds and most of the action is natural, where practices can enhance the students' precision and accuracy of manipulative skills.

*Phase 3: Implementation and Evaluation*

The following phase focuses on the implementation and evaluation of the prepared resource guide. In the evaluation phase, there was a need to critically consider the appropriateness of the resource guide to implement in the local context. The resource guide was implemented and evaluated by a group of teachers. For this purpose, a two-day workshop in a teacher training institute in Kota Bahru, Kelantan was organized. The implementation and evaluation phase were conducted in Kelantan after obtaining approvals to collaborate with the Kota Bahru Teacher Training Institute and the Kelantan State Education Department to conduct the workshop. Initially, 40 school teachers agreed to participate in a two-day workshop. However, only 39 teachers (female=24, male=15) participated in the workshop. The participated teachers' teaching experience average was 14 years in science subjects at schools. The two-day workshop included an introductory session, brainstorming session, and the evaluation of the resource guide session by the school teachers. In the introductory session, the objectives, overall procedure, and the findings of the previous study were introduced. This allowed the teachers to get a clear picture of the study and their important roles in evaluating the resource guide. In the brainstorming session, the teachers were divided into eight groups to discuss related issues and problems in teaching and assessing manipulative skills at their respected schools. After the brainstorming session, the teachers admitted that their students' manipulative skills were weak and much guidance was needed as found in the previous study. The teachers also raised the issues and challenges in teaching manipulative skills. The issues included time constraint, lack of laboratory apparatus, students' attitudes, and safety issues. During the evaluation of the resource guide session, the teachers were requested to go through the complete resource guide, conduct all activities. At the end of the session, they were asked to give feedback on the appropriateness of the resource guide during the interview sessions. The following questions were asked to each participating teacher during the evaluation phase:

1. Can you share your thoughts about the clarity of the explanations given in the resource guide? Please explain.
2. Can the suggested activities be used to determine the level of manipulative skills acquisition among the student?
3. Are the criteria for each proposed category relevant in the context of science learning at school? Please describe.
4. Are the criteria for each proposed category easy to understand?
5. Are the forms in this resource guide easy to use or do you see any difficulty in using it? Please explain.
6. Can the resource guide be implemented at schools? Why?
7. What is your suggestion to make this module more effective?

***(b) Analysis of Data***

In this study, data were collected from observations of teachers' in performing the activities from the resource guide and also from individual interviews. The data were collected and organized into a manageable format. All video and audio data were transcribed. These data were then analyzed qualitatively, which involved the process of coding and categorizing from information that emerged from the collected data (Strauss & Corbin, 2008). The validity and reliability of the interview protocol were done through members check where all the participants agreed to the transcribed data. Categories that emerged during the data analysis were also checked by peer review. Two science education experts were involved in the peer review. Peer review is regarded as one of the most reliable techniques used to enhance the credibility and trustworthiness of qualitative research because of its use of external experts in a given field of study (Merriam, 2009).

## FINDINGS

The analysis of answers that emerged from the interviews is discussed in this subsection.

### a) Clarity of the explanations

During the design and development phase, among the issues to ponder was the suitability of word and sentence structure used to construct the materials in the resource guide. The experiments should be easy to understand for students, whereas the rubrics and instruction for teachers should be well-defined so that teachers can get a clear picture of their role. As seen in the written responses, the teachers agreed that the instruction and explanations in the resource guide were clear, systematic, and suitable for the students. The following excerpts show some of the related responses.

*Yes, the given explanations (in the resource guide) conform to the student's ability. (ST3)*
*Clear and satisfying, can assist teachers in teaching and learning of manipulative skills. (ST11)*
*Yes, it is systematic and helpful for teachers to identify what is to be evaluated during practical. (ST9)*
*The structure of the sentence and language used are simple and clear. (ST12).*

### b) Suitability of the activities or tasks

The teachers who participated in this evaluation phase were experts because of their vast and wide experience in teaching science, and all of them were the examiners for national examination in a science subject at the time of this study. Thus, the teachers played an important role in validating the suitability of the given tasks in determining students' level of competency. All the responses from the teachers regarding this aspect were constructive. They admitted that the activities were suitable to be used for basic experiments. From the observation of the activities, teachers were able to determine students' level of competency in manipulative skills.

### c) Relevancy of the represented criteria in the rubric

The third aspect focused on the relevancy of the criteria in the rubrics in the context of science learning. The criteria were constructed based on the earlier research findings. The following excerpts illustrate the teachers' responses to the third question.

*Yes, it can be used as a guide (to a teacher) and it follows the students' appropriate level of competency. (ST1)*
*It is relevant to the science curriculum for secondary school. (ST13)*
*Yes, it is relevant and follows the curriculum of secondary school. (ST4)*

### d) Clarity of the underlined criteria in the rubric

The science teachers' feedback as "*it is easily understood*" (ST27) and "*simple criteria, easily understood*" (ST36) indicated that the teachers had no problem in comprehending the criteria.

**e) The usability of the Manipulative Skills Competency instrument**

As an instructor, it is important for a teacher to be able to follow the instruction in the resource guide. The important aim of the resource guide is to determine students' ability or level of competency in manipulative skills. Thus, the appropriateness of the instrument needed to be determined. Most of the teachers found this instrument practical in term of its usability. For example, ST25 responded that "*it is suitable, systematic and can be used to determine the students' level of competency, in accordance with the criteria proposed in the rubric*". ST9 said that "*It can also guide the teachers to identify what needs to be evaluated during practical work* and ST28 indicated that the instrument was critical "*to determine which categories of skills that need improvement*" in students' ability or level of competency in manipulative skills.

**f) The suitability of the resource guide to be implemented in schools**

The teachers gave a warm response towards the resource guide as it *"can assist the teachers in identifying the students' competency of manipulative skills at secondary school"* (ST1). It is also "*systematic and comprehensive"* (ST9) and "*can help teachers and students to understand the concepts of manipulative skills based on the criteria proposed in the rubric"* (ST13). The resource guide can also be used to "*assist teachers in school-based assessment"* (ST32) and "*facilitate students to increase their proficiency in manipulative skills"* (ST22).

**g) Improvement of the resource guide**

The final question needed the teachers to give some recommendations for the improvement of the resource guide. Among the recommendations are shown below.

*To add more safety measures (ST2)*
*To use the resource guide to support PEKA assessment (ST8)*
*Come out with a certificate or a form of students' manipulative skills competency at the end of every school year (ST1 & ST14).*

The evaluation phase with the experts was followed by a revision of the resource guide. Most of the modifications and adjustments focused on the structure and arrangement of the resource guide to facilitate its use by science teachers. The instruction was clarified to avoid any difficulties in implementing all the resource guide materials. The workshop received positive feedback from the experts. The experts agreed that this resource guide should be implemented as it can facilitate science learning at secondary school. It is hoped that this resource guide can serve as an important instrument in bridging the gap in science practical work. Once teachers can identify the student level of competency, weaknesses, and strengths in manipulative skills, their focus can become clearer and be further improved until the students achieve the autonomic stage of performing manipulative skills.

## DISCUSSION

This study explored the appropriateness of a developed resource guide in assessing secondary school students' manipulative skills from the perspective of experienced science teachers. Developing a resource guide takes a lot of effort, time, and consideration. After much deliberation, the researchers decided to use a modified framework of the ADDIE model. The ADDIE model is the systematic instructional design model that serves as a basic framework for almost all instructional design models (Isman et al. 2012). The ADDIE model provides an organized way to develop learning activity and instructional strategy to ensure competent assessment instruments can be created for the teachers.

Previous studies found that Malaysia science teachers lack competence and skills in the assessment of manipulative skills during practical work (Ishak, 2014; Ng, 2014). This is in agreement with the findings from this study where the teachers agreed that they had difficulties in assessing students' manipulative skills due to the lack of information about what skills needed to be observed during the laboratory work. The excessive number of students in the science classrooms complicates the matter. It is difficult for teachers to control the classroom. At the same time, the teachers have to ensure that each student acquires the intended manipulative skills.

Moreover, the current assessment guide for Science Practical Work Assessment (PEKA) for UPSR examination (Malaysia Examination Board, 2008) has been seen as not comprehensive enough in assessing students' skills. The current assessment guide only assesses five "constructs" of students' science manipulative skills which are (i) ability to use and handle science apparatus and substances correctly, (ii) ability to handle living and non-living specimens carefully, (iii) ability to draw specimen, apparatus, and substances correctly, (iv) ability to clean apparatus using the correct method, and (v) ability to store apparatus and substances correctly and safely (Ishak, 2014). The instrument developed in this study was based on the extensive analysis of related documents in the assessment of manipulative skills in the primary and secondary school levels. The tasks were not created to evaluate students' knowledge on the science concepts but specifically prepared to understand their manipulative skills in using and handling of the apparatus. The criteria and categories in the instrument were based on the dimensions and elements that emerged from the findings of students' manipulative skills in using and handling scientific apparatus (Fadzil & Saat, 2017). The main categories in the assessment of manipulative skills include (i) systematic operation of tasks, (ii) management of time and workspace, (iii) safety and precautionary measures, (iv) numeracy, (v) scientific drawing, (vi) technical skills in using measuring the cylinder, the thermometer, the Bunsen burner, and the microscope, and (vii) the preparation of slide for the specimen. The categories are more specific and involved more detailed criteria to guide teachers in assessing the students individually.

To address the aforementioned issues, a rubric was developed based on the emerging findings from the first part of this research. Rubrics are well known in the pedagogical plateau. Rubric are advantageous in providing teachers with a guideline to envision what is perceived as effective teaching (Sato, Wei, & Darling-Hammond, 2008) as they serve as a medium that can provide concrete evidence of what needs to be achieved. Jonsson and Svingby (2007) argued that rubrics offer teachers a roadmap to engage with what is perceived as excellent assessment behaviors and practices. According to Allen and Tanner (2006), rubrics not only can be designed to formulate standards for levels of accomplishment but can also be used to guide and improve students' performance. Teachers from this research agreed that the manipulative skills rubric that developed in this study was relevant and practical to be implemented in the context of secondary school science learning. In other words, this rubric can be used to make the appropriate standards of manipulative skills clear and explicit, not only for teachers but appropriate for the students as well. Students can get a clear sense of what the expectations are for a high level of performance and how they can be met as suggested by Huba and Freed (2000), and Luft (1999). The teachers agreed that the resource guide could be extremely beneficial in enhancing their understanding of how manipulative skills can be assessed. Moreover, the resource guide can provide information on the competency level for each student so that students can be more prepared for the implementation of the upcoming science practical examinations.

## CONCLUSION

In light of the findings, it can be concluded that the development of this resource guide is advantageous and beneficial to facilitate teachers in revealing students' manipulative skills competency during practical work. Based on the positive feedback from the experts, this guide can also serve as a powerful instrument for teachers in enhancing the acquisition of science manipulative skills. The research found that minimal research attention has been directed toward exploring the appropriate assessment method in manipulative skills and issues relating to it. Teachers must be aware of the students' different abilities in manipulative skills. This means that the approach in teaching manipulative skills has to be appropriate in order to address the students' competency in handling apparatus. Innovative pedagogical approaches and effective instructional materials may be used to improve teaching and learning to enhance student learning and facilitate the acquisition of manipulative skills. Thus, more research is needed to follow up on the numerous issues raised in this study. For example, a quantitative measure can be conducted to examine the dimensions and elements transpired from this study. The validity of the findings can also be established by carrying out studies with a larger sample of students.

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# The Effect of Chemo-Entrepreneurship Oriented Inquiry Module on Improving Students' Creative Thinking Ability

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## ABSTRACT

The ability of students' creative thinking is not well developed by learning that only focuses on convergent thinking training without giving students problems to face. Therefore, students have difficulty in developing creative thinking ability. Therefore, it is necessary for a learning program to improve student creative thinking ability. This study aims to improve students' creative thinking ability through chemo-entrepreneurship oriented inquiry module (COIM). We used a quasi-experimental research method with a pre-experimental design that involved pretest and posttest of one group. This research was conducted in Chemistry Education Department FPMIPA IKIP Mataram in the fall semester of 2017-2018 academic year. The research subject was 20 students. The findings of the research showed that theCOIM is effective in the learning and teaching process with indicator of percentage given at the pre-test and post-test recapitulation report. The report showed that originality indicator increased from 42% to 60% and were categorized as quite creative. Similarly, fluency indicator increased from 51% to 75% and were categorized as creative, Flexibility indicator also increased from 46% to 65% and were categorized as creative. Lastly, elaboration indicator increased from 60% to 77% and were categorized as creative. This means that the COIM was effective in improving students' creative thinking ability.

**Keywords:** COIM, creative thinking ability.

## INTRODUCTION

Creative thinking is one of the fundamental educational outcomes in the 21st century as the world's economic growth is now innovation-driven (Robinson, 2011). Given the demand for the creativity in the future work force, schools are expected to teach and assess creativity (Voogt & Roblin, 2012). Creative thinking is classified as high order skill and can be seen as a continuation of basic skills (Rudyanto, 2016).The ability of creative thinking is helpful to create an idea or find an alternative solution to solve a problem that occur in

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everyday life. Mahmudi (2010) explains that creative thinking is important because one of the abilities desired by the world of work. This suggests the ability of creative thinking is important to improve.

Creative thinking contains four aspects that include fluency, flexibility, originality, and elaboration (Anwar, Shamim-ur-Rasool, & Haq, 2012). Choridah (2013) gives detailed description of characteristics of creative thinking including a process of originality (ability to make new ideas); fluency (ability to express more than one idea); flexibility (ability to produce different ideas); elaboration (ability to detail ideas). (Siswono, 2010) stated that creative thinking is a process that brings up a new idea for challenging problems. Creative thinkers carry out of ordinary thinking patterns and be able to free themselves from the dominant patterns that have been stored in their brain (Langrehr, 2006). Creative thinking creates opportunities for the development of student personality through efforts to increase concentration, intelligence, and self-confidence (Al-Uqshari, 2005).

However, the current conditions of students' creative thinking ability in Indonesia have not been well developed and are still categorized low. The PISA results for creative thinking ability of Indonesian students ranked 64th out of 65 participating countries in 2012 and ranked 66th out of 74 countries in 2015. The PISA score is an evident for low level of creative thinking of Indonesian students that changed from 382 in 2012 and 386 in 2015 (PISA, 2012). The research results of Wang et al (2017) was an indicator for low level of creative thinking of students that showed originality about 1,57%; flexibility about 1,12%; fluency about 1,03%; elaboration about 0,73%. That means that students had low level of creative thinking ability according to the criteria developed by Brookhart (2010). Faelasofi (2017) stated that the ability of students’creative thinking is low on the aspect of fluency 75%, flexibility 25%, and originality 25%. This results shows low level of students' creative thinking ability according to the scores of three aspects in creative thinking. Based on the indicators of creative thinking, Siswono & Novitasari (2007) categorized creative thinking ability in five level that include level 4 (very creative), level 3 (creative), level 2 (quite creative), level 1 (less creative), and level 0 (not creative). Students are categorized at level 4 as long as they are able to fulfill the three components of creative thinking (fluency, flexibility, and originality). Students can be categorized at level 3 when they are able to fulfill the two components of creative thinking (fluency and flexibility or fluency and originality). Students are categorized at level 2 if they are able to fulfill one component of creative thinking (originality or flexibility). Students are categorized at level 1 if they are able to fulfill the component of fluency only and students are categorized at level 0 if when they are unable to fulfill any of the components of creative thinking.

Creative thinking ability can be trained and developed continuously (Bono, 2007). Students’ ability of creative thinking can be developed through education so students have the ability to access and process data and able to find many possible answers to problems (Jamaluddin, 2011). The creative thinking ability can be developed through high order thinking oriented learning (Sudjana, 2010). In an effort to develop students’ creative thinking ability, teachers need to create non-authoritarian learning environments where students can easily express their ideas, ask questions or generate their own questions. To encourage students’ meaningful learning in such environments, teachers can give challenging problems to students, make teachingfun to students and give rewards to ones who express creative ideas (Suriyani, Hasratuddin, & Asmin, 2015). One effective alternative solution in improving students' creative thinking ability is through the implementation of Chemo-Entrepreneurship Oriented Inquiry Module (COIM).

Inquiry-based learning is one major learning strategy that is given in the science standards and professional development documents (Arisa & Simamora, 2014). Inquiry learning is one of the learning method that can be applied for teaching science (Dewi &

Mashami, 2018). According to Supartono & Anita (2009), is successful in teaching chemistry as students can participate directly in the scientific process in short time. To prepare students with skills in the world of work (vocational skills) creative thinking ability is needed. One of the lessons that have the potential for improving students’ creative thinking ability in entrepreneurship is chemo-entrepreneurship (CEP).

CEP approach is a method used in chemistry teaching and is by that is applicable to daily life. In this approach, students are provided with knowledge and skills in turning raw material into a valuable product by applying chemistry theories into a way of visualization. In this way, students are expected to improve their ability of creative thinking (Wijayati & Rengga, 2009). CEP is a teaching approach used in chemistry that aims to related the theory in chemistry with the real object/phenomenon around human's lives. Therefore, besides learning chemistry, application of CEP approach in the instruction process will enable the students to understand the basic concepts of chemistry theory more easily. It gives students an opportunity to learn the process of turning raw material into valuable products based on chemistry concepts. Hence, it will motivate students to enhance their entrepreneurship spirit. The implementation of CEP instructional approach in chemistry teaching makes learning interesting and joyful (Supartono, 2006). Creative thinking is one skill out of other skills that can be developed through using CEP approach in chemistry teaching. Creative thinking is a typical ability needed for someone to survive, wherever he lives and whatever his profession is. Hence, it is necessary to use CEP instructional approach not only for increasing academic success and learning but also for helping those people for solving daily life problems (Bentley, 2012).

The results of the study conducted by Dewi & Mashami (2018) listed some problems associated with students’ chemistry learning. First, students found some basic chemistry subjects such as colloidal matter difficult to understand due to the characteristics of macroscopic, microscopic and symbolic colloidal. Also, the instructor did not associate lesson material with everyday life. Another problem listed in the study was that the teaching materials were not prepared for the purpose of attracting students' attention. Teaching three aspects of colloidal material that included macroscopic, microscopic through chemo-entrepreneurship can make it easier for students to understand the subject matter because that approach help students to associate material with everyday life. Thus it can be concluded that the development of chemo-entrepreneurship oriented inquiry modules is needed for teaching colloidal material for prospective chemistry teachers and students at IKIP Mataram. Involving the interrelationships between concepts and daily life will make learning chemistry more meaningful and enjoyable.

Previous studies such as Kurniawan (2013) and Deta & Widha (2013) stated that teaching through guided inquiry model can improve students’ creativity. Students learn about 10% of what they read, 20% of what they hear, 30% of what they see, 50% of what they see and hear and hear, and 90% of what they do (Supartono & Anita, 2009). Research conducted by (Rusilowati, 2009) showed that students’ creativity can develop when they like and be interested in science. In addition, Yahya (2014) said that students’ creativity increases through project-based learning. According to Suciati, Vincentrisia, and Ismiyatin (2015), students creativity can be improved through using the 5E Learning Cycle model in lesson implementation.

Many researchers conducted research on creative thinking and discussed the factors that affect creative thinking. Gregory, Hardiman, Yarmolinskaya, Rinne, and Limb (2013), for example, discussed that students’ creative thinking ability develop by the help of several factors used in classrooms including giving chances to students to ask questions. Classrooms often give too little chances for students to think creatively. However, the abilities of creative thinking and problem-solving can be shaped in various ways. For example, instructor can encourage students to find connection between different ideas and give students chance to offer various solutions to complex problems (Brooks, 1999; Sternberg & Williams, 1996). Treffinger, Schoonover, & Selby (2012) suggested encouraging students to explore, question, experiment, manipulate, listen, and solve the problems they face in order to improve their creativity. Additionally, students will learn better, be more critical in thinking, and be able to think creatively if they learn in a safe environment (Brookfield, 2017). A safe environment will make students feel more comfortable to deliver their opinion and ideas, to take risks, to be open to changes, and to be creative.

This study aims to improve students' creative thinking ability through implementation of chemo-entrepreneurship oriented inquiry module (COIM). COIM model is based on inquiry processes in learning and chemo-entrepreneurship approach. The learning steps in the COIM model are problem orientation, formulating problems, writing hypotheses, making observing and collecting data through chemo-entrepreneurship activities. The results of implementation the COIM model in the classroom and the indicators in creative thinking ability including a process of originality, fluency, flexibility, and elaboration are described in this article.

## METHODS

We used a quasi-experimental research method with a pre-experimental design that focused on chemo-entrepreurship oriented inquiry module (COIM) implementation in studying, learning and teaching to improve students' creative thinking ability. This research aimed to improve students' creative thinking ability by using the COIM model. Data in this research is students' creative thinking ability indicator that can be measured through student's ability to solve the designed test.

The form of pre-experimental design in this study was One Group Pretest-Posttest Design (Sugiyono, 2013). The shape of the design is illustrated in Table 1.

**Table 1.** *Pre-experimental design*

| Subject | Pretest | Posttest |
|---|---|---|
| One Group | $O_1$ | $O_2$ |

Information: $O_1$ = Pretest value before learning through COIM. $O_2$ = Posttest value after learning through COIM.

This research was conducted in Chemistry Education Department FPMIPA IKIP Mataram in the fall semester of 2017-2018 academic year. The research subject was 20 students. The sampling technique in this study is saturated sampling, namely the technique of determining the sample if all members of the population are used as samples (Sugiyono, 2013).

### a) Validity of the creative thinking instrument

The creative thinking instrument is validated by an expert before it was applied. The instrument was validated using the validation sheet based on five scoring Likert scale items including: 5 = very valid, 4 = valid, 3 = quite valid, 2 = less valid, 1 = invalid. Obtained score from the validators is converted into five-scale qualitative data (Bahtiar, & Prayogi, 2012) as shown in table 2.

**Table 2.** *The validity criteria of the instrument of creative thinking ability*

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

An instrument of creative thinking ability is considered as valid when the minimum of validity degree is valid. If the validity degree is less than valid, that means the instrument has to be revised. The results obtained from the validation test by experts about 4.25% with category very valid. After the instrument of creative thinking had been validated by experts, it was applied to the students who had taken basic chemistry courses. The trial results were analyzed using the Rasch Model Minister statistic. The results showed that the probabilities of all items were above 5%. Thus, it can be concluded that all ten items are valid as shown in table 3.

**Table 3.** *The validity Rasch Model*

DIF class specification is: DIF=$S1W1

| Person CLASSES | SUMMARY DIF CHI-SQUARED | D.F. | PROB. | BETWEEN-CLASS UNWTD MNSQ | t=ZSTD | Item Number | Name |
|---|---|---|---|---|---|---|---|
| 10 | 2.8666 | 9 | .9693 | 1.3216 | .7771 | 1 | E1 |
| 10 | 3.7002 | 9 | .9300 | 1.3439 | .8161 | 2 | E2 |
| 10 | 1.5118 | 9 | .9971 | .3864 | -1.5715 | 3 | E3 |
| 10 | 3.1772 | 9 | .9568 | 2.1287 | 1.9797 | 4 | E4 |
| 10 | 1.0084 | 9 | .9994 | .2034 | -2.4639 | 5 | E5 |
| 10 | 1.4163 | 9 | .9977 | 2.0141 | 1.8301 | 6 | E6 |
| 10 | 1.3591 | 9 | .9981 | .5932 | -.8595 | 7 | E7 |
| 10 | 3.9172 | 9 | .9168 | 3.1346 | 3.1069 | 8 | E8 |
| 10 | 2.1917 | 9 | .9880 | .5800 | -.8995 | 9 | E9 |
| 10 | 1.6292 | 9 | .9961 | .5851 | -.8840 | 10 | E10 |

**b) Reliability of the creative thinking instrument**

The reliability of the instrument was analyzed using a statistics method called Rasch Model K-R 20 (Cronbach Alpa).The reliability value for 10 items was 0.81 with very high criteria as shown in table 4.

**Table 4.** *The Reliability Rasch Model K-R 20*

SUMMARY OF 18 MEASURED Person

| | TOTAL SCORE | COUNT | MEASURE | MODEL S.E. | INFIT MNSQ | INFIT ZSTD | OUTFIT MNSQ | OUTFIT ZSTD |
|---|---|---|---|---|---|---|---|---|
| MEAN | 12.1 | 8.0 | .01 | .51 | .97 | -.1 | 1.01 | .0 |
| P.SD | 4.8 | .0 | 1.15 | .04 | .50 | 1.1 | .56 | 1.1 |
| S.SD | 5.0 | .0 | 1.18 | .04 | .52 | 1.1 | .57 | 1.1 |
| MAX. | 19.0 | 8.0 | 1.70 | .60 | 1.95 | 1.8 | 2.26 | 1.9 |
| MIN. | 4.0 | 8.0 | -2.03 | .47 | .28 | -2.1 | .30 | -2.0 |

REAL RMSE .55 TRUE SD 1.01 SEPARATION 1.82 Person RELIABILITY .77
MODEL RMSE .51 TRUE SD 1.03 SEPARATION 2.03 Person RELIABILITY .81
S.E. OF Person MEAN = .28

Person RAW SCORE-TO-MEASURE CORRELATION = 1.00
CRONBACH ALPHA (KR-20) Person RAW SCORE "TEST" RELIABILITY = .81 SEM = 2.13

### c) The effectiveness of the COIM model

The effectiveness of the COIM model was evaluated through students' improvements of creative thinking ability. Creative thinking ability is evaluated using the scoring technique adapted from Ismaimuza creative thinking essay test, where the highest score is 4 and the lowest score is 0. The indicators of creative thinking ability in this study are originality, fluency, flexibility, and elaboration. The score is calculated using the following equation (Rahman, 2017):

$$x = \frac{\textit{The Acquired Score}}{\textit{The Maximum Score}} x\ 100\%$$

With the following criteria:
81—100 =Highly creative
65—80 = Creative
40—64 = Quite creative
< 40 = Less creative

## FINDINGS

Creative thinking ability in this research consisted of originality, i.e., having new ideas to solve the problem, fluency, i.e., generating many ideas in various categories, flexibility,i.e., the ability to produce various ideas and elaboration, i.e., the ability to detail ideas (Kim, 2006). The creative thinking ability result in this research is shown in Table 5 below.

**Table 5.** *Summary for descriptive analysis result*

| Component | Pre-test | Post-test |
|---|---|---|
| Maximum Score | 70 | 80 |
| Minimum Score | 20 | 60 |
| Range | 50 | 20 |
| Average | 45,75 | 72,25 |
| N | 20 | 20 |

The table 6 below compares the pre-test and the post-test results. The pre-test results shows that there were 16 students in the less creative category (36.2 %), 2 students in the quite creative category (4.6%), 2 students in the creative category (4.6%), meanwhile there was none in highly creative category. After the treatment, the post-test shows that there were 8 students in the highly creative category (28.9%), 6 students in the creative category (21.7%), 6 students in the quite creative category (21.7%), and none in less creative category. The table 6 below compares the number of students at each category.

**Table 6.** *Students creative thinking ability test*

| Component | Pre-test | Post-test |
|---|---|---|
| Less Creative | 16 | 0 |
| Quite Creative | 2 | 6 |
| Creative | 2 | 6 |
| Highly Creative | 0 | 8 |
| N | 20 | 20 |

The percentages for each creative thinking ability indicator was reported for pre-test and post-test as shown in table 7.

**Table 7.** *Percentage of Creative thinking ability indicator*

| Creative thinking ability indicator | Pre-test (%) | Post-test (%) |
|---|---|---|
| Originality | 42 | 60 |
| Fluency | 51 | 75 |
| Flexibility | 46 | 65 |
| Elaboration | 60 | 77 |
| N | 20 | 20 |

Based on the results shown at table 7, students' creative thinking ability increased. This can be seen from creative thinking ability indicator percentages reported for pre-test and post-test. For the pre-test, students' originality was 42%, fluency was 51%, flexibility was 46%, and elaboration was 60%. Meanwhile, for the post-test, the creative thinking ability increased for each indicator. Students' originality increased to 60%, fluency increased to 75%, flexibility increased to 65% and elaboration increased to 77%.

## DISCUSSION and CONCLUSION

The data analysis results showed that creative thinking ability for all indicators increased after the students were taught using the COIM model. Therefore, from that research, we can safely say that the COIM model is effective for improving students' creative thinking ability. The COIM model can give students opportunity to turn raw material into valuable products based on the chemistry concepts. Hence, it motivates students to enhance their entrepreneurship spirit. However, the results of the study also shows that the increase in originality indicators is still at low category compared with other indicators (fluency, flexibility, and elaboration). This is because original/unique/new thinking is the essence of creativity. This statement is in line with Azzam's opinion (Brookhart, 2010) as he stated that creativity is a process of producing original and valuable ideas. Furthermore, Mednick (Treffinger et al., 2012) explains that creativity is the process of combining existing ideas with unusual and original new ideas. When viewed from a cognitive point of view, creativity is categorized into the highest cognitive level, namely the ability to create (Brookhart, 2010). Therefore, being creative (being able to produce original ideas) is not an easy matter. New and original ideas will be formed if someone really knows, understands, be able to apply, analyze, and evaluate each aspect that is relevant to the problem that is to be solved.

In the process of classroom learning, students are grouped heterogeneously to facilitate discussions and share information about issues of knowledge and understand the concepts. The steps of the COIM model were explained earlier namely: 1). problem orientation; 2). problem formulation; 3) writing hypotheses; 4) making observations and collecting data through chemo-entrepreneurship activities. The COIM learning model in chemistry learning process provide meaningful experiences for students in the form of knowledge or information presented in simple real events. Additionally, it provides positive benefits in strengthening students' understanding regarding natural phenomena that occur. Thus students are able to find out the concepts or information that exist and directly apply into the test that measures creative thinking skills (Kusuma, 2010). The COIM learning model aims to study the process of turning natural materials into products so that students more easily understand the concept being taught and grow entrepreneurship spirit in learning chemistry. In addition, students can practice making bar soap which makes it easier for them to understand and remember the material that had been taught.

Developing creative thinking ability for students requires an instructor who is also creative. The creative instructor is a person who is able to realize students' abilities and guide students in accordance with the expected purposes (Carter & McRae, 2014; Craft, Hall, & Costello, 2014; Sternberg & Williams, 1996). Creative instructors will seek for new strategies to develop potentials of the students. The instructor should attempt to create a comfortable and pleasing learning environment for the students in a way that enable them to explore all the abilities they have. The creative thinking ability is one of the four skills needed in the 21st century. The 21st century individuals need to have competence in five main skills, namely: (1) being able to adapt (adaptability); (2) having complex communication skills (complex communication skills); (3) having problem-solving skills (problem-solving skills); (4) having self-management and self-development skills; and (5) a system of systems thinking (Kim, 2006). Supartono (2006) stated that chemo-entrepreneurship-based chemistry learning model provides opportunities for students to be creative and motivate students to solve problems by introducing chemistry materials as part of everyday life.

The results are supported by Listari (2018) who found the average value of the experimental class was 74% and the average result of the control class was 71, 35%. The application of Chemo-entrepreneurship oriented PBL to the concept of the colloidal system has a good influence on student learning outcomes. It was based on 2.593 t-tests> t-table 1, 669 with the average cognitive results of the experimental class being 76.95 and the control class being69.33. For classroom effectiveness the experiment group was 74.59 and control group was67.29. Based on the results of the study it can be concluded that there is an influence of chemo-entrepreneurship-oriented model on student chemistry learning outcomes. It is in line with the results found by Marwah, Dewi & Mashami(2018) as they found that the experimental class were 63%, 74% and the control class were 66%, 68%. The results of the study showed how chemo-entrepreneurship based TAI type cooperative learning model increased students' entrepreneurial motivation. So it can be concluded that there is a positive relationship between chemo-entrepreneurship-based TAI type cooperative learning model and entrepreneurial motivation. Andriani, Muhali & Dewi (2018) stated that the application of the Chemo-entrepreneurship oriented POE (Predict-Observe-Explain) learning model had significant effect on students' conceptual understanding. Nurwahidah, Suryati & Dewi (2017) who used chemo-entrepreneurship oriented PBL, found that the value of sig. (2-tailed) 0,000 <0,05 for creative thinking ability with an average value of experimental class post-test of 89% and control class of 74%. They concluded that teaching through chemo-entrepreneurship oriented PBL model has a positive effect on the students' creative thinking ability. Zubaidah, Fuad, Mahanal, & Suarsini (2017) showed that there was a difference in students creative thinking skills for different models where highest creative thinking skills were exhibited by the students who were taught using the Differentiated Science Inquiry integrated with mind Map model. Mirzaie, Hamidi, Anaraki (2009) stated that use of science activities and brainstorming teaching method, teachers can increase their children capacity with respect to the core dimensions of creativity; fluency, flexibility, originality and elaboration.

Finally, it can be concluded that the implementation of Chemo-entrepreneurship oriented inquiry module (COIM) can improve students' creative thinking ability in learning and teaching process. The percentage given at the pre-test and post-test recapitulation report is evident for this conclusion. Pre-test score was 42%for originality, 51% fluency, 46% for flexibility, and 60% for elaboration. Meanwhile, during post-test, the creative thinking ability increased for each indicator. Students' ability about originality increased to 60%, their fluency increased to 75%, their flexibility increased to 65% and their ability of elaboration increased to 77%. This research implies that implementation of Chemo-entrepreneurship oriented inquiry module (COIM) is one good option for improving students' creative thinking ability. This learning model should be implemented in various fields of education. Research with the same topic should be conducted in the future within different subject matters and in different contexts.

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# The Importance of the Concept of Water in Biology Education

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## ABSTRACT

The purpose of this study is to disclose the units and topics including the concept of water within 9th, 10th, 11th and 12th grades' biology textbooks that were chosen by the Ministry of National Education (MoNE) Head Council of Education and Morality (HCEM), and provide an overview of the whole content that mentions the concept of water. This qualitative study employed the document review method. The ratio of the number of units including the concept of water in the reviewed biology textbooks*/total number of units-number of topics/*total number of topics are, respectively 3/3-9/9 for 9th grade, 2/3-8/11 for 10th grade, 3/3-10/12 for 11th grade and 4/4-8/9 for 12th grade. In general, it has been observed that these units/topics address the structure and characteristics of water; its role on nutrition, respiration, circulation, excretory, reproduction, movement, behaviour, energy flow and metabolic events; its significance on living structure, natural resources, energy resources, living spaces, environmental problems and health; and its relationship with osmotic pressure, enzymes, hormones, professional areas and some structures of living beings. Findings revealed that water has a special place in biology education and biology education is an important tool in conveying the significance of water for the living beings. Further studies may focus on the place of water in teaching various disciplines.

**Keywords:** Water, biology education, textbooks

## INTRODUCTION

Water is one of the main sources to sustain life. It is very important for preserving life. It is known about the role of water in various forms on earth, in the living structure and biochemical reactions. Water is handed down to future generations, being protected from contamination. The importance of water in the past, present and future highlights the importance of raising individuals who are conscious about these topics, since all that is known about water to be handed down through generations. Education and training in schools in the life sciences, especially biology education, has especially an important role in ensuring the information transfer.

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Textbooks are the main education-training materials, providing great benefit for both teacher and students. Textbooks are keeping their importance despite many changes in the educational system (Yapıcı, Coşkun and Akbayın, 2009). Textbooks are the main documents that guide and teach students in accordance with the goals of the subject, and revealing the topics in the curricula in a planned manner (Ünsal and Güneş, 2004).

Water has a wide range of characteristics that can be discussed in many fields, including physics, chemistry, medicine, health, biology, environment, geography and geology. Thanks to this multifaceted structure of water, it is possible to encounter doctrines on different characteristics of water in various disciplines. In this context, this study is necessary in terms of understanding the importance of water, which is considered as both the existence in any environment and life, for the life science and especially biology education, and determining how much of what is known about water is conveyed through biology education.

There is a wide literature on the way subjects are thought in biology textbooks (Jablon, 1992; Storey, 1992; Myers, 1997; Roth, Bowen and McGinn, 1999; Seçgen and Morgil, 2000; Mülayim and Soran, 2002; Köse, Ayas, Coştu and Karamustafaoğlu, 2004; Uzun and Sağlam, 2003; Özay, 2005; Atıcı, Keskin Samancı, and Özel, 2007; Özay and Hasenekoğlu, 2007; Kete and Acar, 2007; Anılan, Balbağ, Anılan, Görgülü and Çemrek, 2007; Çobanoğlu, Şahin and Karakaya, 2009; Köse, 2009; Dikmenli, Çardak and Öztaş, 2009; Yapıcı et al., 2009; Yürümez, 2010; Coşkun, 2011; Şen, 2011; Türköz, 2011; Üstün, 2011; Akgümüş, 2012; Anagnostopoulou, Hatzinikita and Christidou, 2012; Özbaş and Soran, 2012; Aslan Efe, Efe and Yücel, 2012; Kete, Horasan and Namdar, 2012; Çetin and Çakır, 2013; Arıkan, 2014; Şen and Nakiboğlu, 2014; Chaisri and Thathong, 2014; Adnan 2015; Gündüz, Yılmaz and Çimen, 2016; Ide, Thiel and Fischendler, 2019).

However, there is limited literature, in terms of content and number, on how water subject is included in biology textbooks. Since water has a vital importance for the living beings, it is necessary to teach the concept of water. Biology textbooks are one of the most important tools that are used in the education to convey the young individuals. Thus, the problem status was determined as "the importance of the concept of water in biology education".

The purpose of this study is to disclose the units and topics including the concept of water within 9$^{th}$, 10$^{th}$, 11$^{th}$ and 12$^{th}$ grades' biology textbooks that were chosen by the Ministry of National Education (MoNE) Head Council of Education and Morality (HCEM), and provide an overview of the whole content that mentions the concept of water.

## METHODS

This qualitative study employed the document review method. Document review comprises the analysis of the written materials that include information about the case or cases projected to research about" (Şimşek and Yıldırım, 2016). Document analysis is the process of collecting current records and documentation related to the study to be carried out, code them according to a certain norm or system, and review" (Çepni, 2009).

The universe of the study consists of the secondary education 9$^{th}$, 10$^{th}$, 11$^{th}$ and 12$^{th}$ grades' biology textbooks to be studied during the 2016-2017 school year in Turkey. The sample of the study includes 9$^{th}$, 10$^{th}$, 11$^{th}$ and 12$^{th}$ grades' biology textbooks that were chosen by the MoNE (Appendix 1).

In this study the secondary education 9$^{th}$, 10$^{th}$, 11$^{th}$ and 12$^{th}$ grades' biology textbooks were analysed based on the content and the concept of water in the units and topics. The activities at the end of units within the reviewed books were not included in this analysis. Units and topics that mention the concept of water within the reviewed textbooks were determined during the process of analysis, and numerical data were presented as to how many units and topics included this concept. In addition, the content that used the concept of water within the textbooks were summarised and reported.

## FINDINGS

According to the findings of this study, the units and topics related to the concept of water in the biology textbooks at each class level are distributed as follows.

**Table 1.** *Distribution of units and topics including the concept of water within the 9th grade biology textbook*

| Class | Unit | Subject | Page No |
|---|---|---|---|
| 9 | 1. Biology, the life science | 1. The nature of scientific knowledge | 18, 20, 21 |
| | | 2. Common characteristics of living beings | 31, 32 |
| | | 3. Basic components in the structures of living beings | 38, 40, 41, 42, 43, 44, 49, 50, 52, 54, 56, 58, 60, 63, 64, 66, 68, 70, 73 |
| | 2. The world of living beings | 1. Cell and cell theory | 80, 90, 91, 92, 94, 98, 100, 101 |
| | | 2. The variety and classification of living beings | 111 |
| | | 3. The kingdom of living beings | 124, 125, 126, 127, 130, 131, 132, 138, 139, 141, 142, 144, 145, 146, 147, 148, 149, 151, 156, 157, 158, 159, 160, 161, 163, 164 |
| | 3. Current environmental issues and human | 1. Current environmental issues and human | 174, 175, 179, 181, 182, 184, 186, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 199, 206, 208, 211 |
| | | 2. Natural resources | 222, 223, 225, 226, 228, 229 |
| | | 3. Biological diversity. | 237, 239, 240, 245 |

The related units and topics in the 9th grade biology textbook are: "Biology, the life science" unit which includes the nature of scientific knowledge, common characteristics of living beings, basic components in the structures of living beings; "the world of living beings" unit which includes cell and cell theory, the variety and classification of living beings, the kingdom of living beings; "current environmental issues and human" unit which includes current environmental issues and human, natural resources, biological diversity. The proportion of the number of units related to the concept of water in 9th grade biology textbook to the total number of units is 3/3, while that of the number of topics to the total number of topics is 9/9.

**Table 2.** *Distribution of units and topics including the concept of water within the 10th grade biology textbook*

| Class | Unit | Subject | Page No |
|---|---|---|---|
| 10 | 1. Reproduction | 1. Mitotic and asexual reproduction | 11, 13 |
| | | 2. Meiosis and sexual reproduction | 22 |
| | 3. Our world | 1. The ecology of ecosystem | 104, 105, 106 |
| | | 2. Factors affecting living beings | 106, 107, 108 |
| | | 3. Nutrition types | 113 |
| | | 4. Matter and energy flow | 118, 119, 120 |
| | | 5. The impact of human activities on ecosystem | 122, 123, 125 |
| | | 6. Biomes | 127, 128, 129, 131, 132, 133, 134, 135, 136, 137 |

The related units and topics in the 10th grade biology textbook are: "reproduction" unit which includes mitotic and asexual reproduction, meiosis and sexual reproduction; "our world" unit which includes the ecology of ecosystem, factors affecting living beings, nutrition types, matter and energy flow, the impact of human activities on ecosystem, biomes. The proportion of the number of units related to the concept of water in 10th grade biology textbook to the total number of units is 2/3, while that of the number of topics to the total number of topics is 8/11.

**Table 3.** *Distribution of units and topics including the concept of water within the 11th grade biology textbook*

| Class | Unit | Subject | Page No |
|---|---|---|---|
| 11 | 1. Energy conversion in living beings | 1. Life and energy | 5, 6 |
| | | 2. Photosynthesis, | 11, 15, 16, 17, 18, 24, 26, 27 |
| | | 3. Chemosynthesis, | 35, 36 |
| | | 4. Respiration | 40, 46, 49, 50, 53, 56, 57, 58 |
| | 2. Human physiology | 2. Nerves hormones and homeostasis | 81, 88, 90, 91, 93 |
| | | 4. Digestive system | 127, 131, 134, 135, 137, 138, 139 |
| | | 5. Circulation system | 151, 161 |
| | | 6. Respiratory system | 171, 174, 175 |
| | | 7. Urinary system | 183, 185, 186, 187, 190, 192 |
| | 3. Behaviour | 1. Behaviour | 202, 203, 207 |

The related units and topics in the 11th grade biology textbook are: "energy conversion in living beings" unit which includes life and energy, photosynthesis, chemosynthesis, respiration; "human physiology" unit which includes nerves hormones and homeostasis, digestive system, circulation system, respiratory system, urinary system; "behaviour" unit which includes behaviour. The proportion of the number of units related to the concept of water in 11th grade biology textbook to the total number of units is 3/3, while that of the number of topics to the total number of topics is 10/12.

**Table 4.** *Distribution of units and topics including the concept of water within the 12th grade biology textbook*

| Class | Unit | Subject | Page No |
|---|---|---|---|
| 12 | 1. Gene to Protein | 2. Genetic Code and Protein Synthesis | 43 |
| | 2. Plant physiology | 1. Structure growth and movement of plants | 55, 58, 59, 61, 62, 64, 65, 66, 70, 71, 74, 79, 80, 84, 85, 86, 90, 91 |
| | | 2. Transfer of matter in plants | 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 111 |
| | | 3. Sexual reproduction in plants | 119, 123, 125 |
| | 3. Community and population ecology | 1. Community ecology | 138, 139, 140, 141, 142 |
| | | 2. Population ecology | 149, 154, 157, 159 |
| | 4. Beginning of life and evolution | 1. Beginning of life | 172, 175, 176, 179, 181, 182, 183, 186 |
| | | 2. Evolution | 191, 194 |

The related units and topics in the 12th grade biology textbook are: “gene to protein” unit which includes genetic code and protein synthesis; "plant physiology " unit which includes structure growth and movement of plants, transfer of matter in plants, sexual reproduction in plants; "community and population ecology" unit which includes community ecology, population ecology; "beginning of life and evolution" unit which includes beginning of life, evolution. The proportion of the number of units related to the concept of water in 12th grade biology textbook to the total number of units is 4/4, while that of the number of topics to the total number of topics is 8/9.

The content related to the concept of water that is mentioned in these units and topics can be summarised as follows:

*Infiltration of water into living structures:*

- Body of living organism, saliva, blood plasma, urine, bile, mixture in the small intestine, cytoplasm
- Tree, seed, vegetables and fruits

*The importance of water for the living beings:*

- Ensuring continuation of life
- Having structural and functional importance for the living beings
- Protecting both cell structure as well as the shape of the eyeball, saving the body from toxins and wastes, ensuring regular activity of the organs, loss of weight, the beautifying of skin, anti-aging, nourishment, growth
- Having positive effects on human psychology
- Transporting of bacteria, pollens, spores, and some fruits through water

- Being able to recognise the chemical structure of water and return where they were born
- Water is used in different areas of life, such as cleaning, irrigation, water transportation, tourism, dialysis, scientific experimentation and for health purposes.

*Some events where water plays a role in a living body:*
- Diffusion, osmosis, plasmolysis, deplasmolysis, turgor, osmotic pressure, turgor pressure
- Transporting of nutrients and oxygen
- Enzyme activity
- Transpiration, oedema
- Enabling motion in the plant roots, ensuring transport of materials in plants, opening and closure of stoma, germination, capillarity in plants, root pressure, cohesion-tension theory

*Certain prevalent structures in the bodies of living entities in relation to water*
- Contractile vacuole, silk, whip, thread-like structures
- Leaves
- Root, root-like structure, root absorbent hairs, zone of maturation in the root
- Transfer tissue (xylem, trachea, tracheid), epithelium, fungus tissue, cuticles, suberin
- Stoma, hydathode, guard hairs, thorn-like structure
- Parenchyma (Ventilation, transfer, storage)
- Hormones (ADH, aldosterone, gibberellin, ethylene, abscisic acid)
- Gill, fin, swim bladders
- Skin
- Hypothalamus
- Large intestine
- Kidneys (nephrons, glomerulus capillaries, bowman capsule, nephron tubes)
- Lipoproteins in alveoli

*Importance of water for the health:*
- Drinking two litres of water a day, not drinking hard water, consuming plenty of water for an acid accumulating in the body, a well-balanced diet, and diarrhoea, the removal excess water

*Water as a habitat for some living beings:*
- Certain bacteria, certain archaebacteria, algae, phytoplanktons, plankton, euglena, protista, certain plants, aquatic plants, reed maces, bryophytes, yeast, some worms, prawn, aquatic insects, fish, waterfowl, larval stage of amphibians, some mammals (seals, dolphins, otters, penguins)

*Water as a breeding ground for some living beings:*
- Amphibians, mayflies, moss, reptiles

*Water in biochemical reactions:*
- Photosynthesis, chemosynthesis, aerobic respiration, glycolysis, digestion, fat metabolism, hydrolysis, dehydration, ATP break down, transport of carbon dioxide

*Water on the surface:*

- The forms that water takes such as sea, lake, stream, river, brook, creek, watercourse, cloud, rain, dew, humid, water vapour, ocean, glacier, groundwater, thermal waters, wetlands, fresh waters, acid rain, mist, snow, aquatic biomes
- Existence of water in 3/4 of the earth's surface, existence of water in soil and in the atmosphere, non-existence of water on Mars
- Water cycle
- Relation between water vapour and global warming
- Water scarcity and drought
- Water-led erosions, soil loss and non-storability of rain water
- Depletion of water resources and destruction of habitats for various reasons
- Water as the source of oxygen in the atmosphere
- İnfluence of rainforests on surface waters
- Water as an abiotic factor
- Water wells and water drilling rig
- Competition of living beings for water
- Determining the boundaries of community, and water in the distribution of terrestrial species
- Water in order to sustain the presence of a given population
- Unspoiled natural spring water
- From sulphur and nitrogen, the formation of sulfuric acid and nitric acid, dissolution of limestone in water and carbon dioxide formation, bones and shells in water turning into rocks with high amount of minerals

*Water as an energy source:*

- Hydro-electric power, geothermal power, potential and kinetic energy, water fora

*Water pollution*:

*Causes*

- İnfiltration by various ways in water of domestic, industrial, agricultural wastes, contaminants, sewage, petroleum, untreated sewage, radioactive wastes, heavy metals, toxic substances
- Eutrophication
- Oils poured in sink
- Parasites in water
- Ballast water

*Results*

- Transmission of disease as a result of contact with polluted waters and sewage, and the negative impact on human health

*Methods of prevention*

- Reverse osmosis application
- Bio-remediation, cleaning with archaebacteria, protista, bacteria, fungi, alg, and plants
- Conscious living
- Controlled disposal of industrial and domestic wastes
- Monitoring fertiliser and chemical drug usage in agriculture
- Application of water boiling and domestic treatment systems to avoid parasites in water
- Washing fruits and vegetables with a lot of water to protect from agricultural drugs

- Using water thriftily without polluting the water

*Physical and chemical properties of water:*
- Water is inorganic
- Water is formed by one oxygen and two hydrogen atoms
- Water has Cohesion force
- Water is a solvent
- Water's specific heat is higher than that of many other compounds
- Water transforms into gas when heated; water vapour condensing with cold air in order to form rain
- Water has the highest specific weight at +4 C'
- Different water types have acidic, basic and neutral forms (sea water, fruit juice, pure water, etc.)
- Water becomes hardened depending on the mineral it contains
- Water transmits the energy in lightning quickly

*Fields of occupation related to water:*
- Aquaculture, marine biology, marine biologist, environmental scientists specializing in fresh water and seas

*Other information about water:*
- We show a withdrawal reflex when touching hot water
- Putting chrysalises in hot water for obtaining silk from butterfly pupae
- Efforts to develop drought-tolerant plants are ongoing.
- Mushrooms help plants to extract water from the ground.
- Bacteria cannot survive in 100-degree boiling water however; endospores continue to live.
- Arkebacterists leave a bright blue colour in hot water.
- Water insoluble substances (such as starch, cellulose, phospholipid, fatty acids, cuticula etc.)
- Water that separates acids from bases.
- Water quality

## DISCUSSION

Water is a limited and natural resource that is one of the most significant requirements for life. It has a vital role in maintaining life and no alternative that can substitute it (Pamuk Mengü and Akkuzu, 2008; Çankaya, 2014).

It is important to create social awareness and to raise individuals who are conscious about water in order to protect water resources and ensure water sustainability. This important need can be met through education (Çankaya, 2014).

Biology discipline serves as a source for various information on water. Thus, biology education and the content of the textbooks become crucial in transferring water-related knowledge to future generations.

This study analyzes the concept of water as mentioned in the biology textbooks for 9$^{th}$ 10$^{th}$, 11$^{th}$ and 12$^{th}$ grades, which were accepted by the Ministry of National Education [MoNE] and the Head Council of Education and Morality [HCEM].

The 9$^{th}$ grade biology textbook covers three units and nine topics in total. All units and topics include the concept of water. The concept of water was most encountered in the "The world of living beings" unit and in the "The kingdom of living beings" topic. On the other hand, it was least encountered in the "Biology, the life science" unit and in the "The variety and classification of living beings" topic.

The 10th grade biology textbook covers three units and eleven topics in total. Two units and eight topics include the concept of water, while it was most encountered in the "our world" unit and in the "biomes" topic. On the other hand, it was least encountered in the "reproduction" unit and in the "meiosis and sexual reproduction" and "nutrition types" topics. However, the concept of water was not encountered in the "growth and development" topic in the first unit and the "modern genetic practices" and "genetics and biological diversity" topics in the second unit.

The 11th grade biology textbook covers three units and twelve topics in total. Three units and ten topics include the concept of water, while it was most encountered in the "human physiology" unit and in the "photosynthesis" and "respiration" topics. On the other hand, it was least encountered in the "behavior" unit and in the "life and energy", "chemosynthesis" and "circulation system" topics. However, the concept of water was not encountered in the "tissues" and "support and motion system" topics in the second unit.

The 12th grade biology textbook covers four units and nine topics in total. Four units and eight topics include the concept of water, while it was most encountered in the "plant physiology" unit and in the "structure growth and movement of plants" topic. On the other hand, it was least encountered in the "gene to protein" unit and in the "genetic code and protein synthesis" topic. However, the concept of water was not encountered in the "discovery and importance of nucleic acids" topic in the first unit of this textbook.

While showing that the textbooks increasingly included materials related to water and its importance, unfortunately little emphasis was made on the role of water in chapters related to proteins and nucleic acids even though the importance of water in the nucleic acid and protein structures was highlighted by Chaplin, 2001.

The content in the analyzed textbooks where the concept of water was mentioned can be summarized as follows.

- Water forming a large part of the living body.
- Water's importance for the living beings in terms of structure and functionality.
- Water's role in certain events taking place in the living body, including the operation of enzymes, sweating, and edema.
- Water's relation with some structures in the living body, including with stem, leaves, tissues, organs, hormones, skin, contractile vacuole, cilium, and flagellum.
- Water's importance for health.
- Water as a habitat and breeding ground for some living beings.
- Water's role in biochemical reactions including photosynthesis, chemosynthesis, respiration, hydrolysis, dehydration and the transfer of carbon dioxide.
- Water is on the surface, on earth and in the atmosphere. It takes different forms such as sea, lake, river, and stream. Also, water has a relation with the oxygen resource in the atmosphere such as water cycle, water scarcity, water resources, waterborne erosion, drought etc.
- Water as the hydro-electric power and geothermal power.
- Water pollution caused by eutrophication, domestic, industrial, agricultural, and radioactive wastes that mix in water, heavy metals, and parasites. Unfortunately, water pollution leading to adverse health outcomes. Though water pollution can be prevented by living consciously, bioremediation, controlled disposal of industrial and domestic wastes, treatment, and monitoring agricultural pesticides.

- Composed of one oxygen and two hydrogen atoms, water has an inorganic structure, a certain degree of hardness, specific heat, and the ability of transmutation.
- There are water-related occupational groups, including aquaculture, marine biologist, environmental scientist etc.
- Living beings can show distinct reactions to hot water: some materials are insoluble, water plays a role in the determination of acid or base number, and it has its quality.

One or more of the abovementioned information obtained about water are supported by the studies conducted by Sağlam and Bellitürk (2003); Bayazıt Hayta (2006); Kuşak (2006); Akın and Akın (2007); Boysan and Şengörür (2009); Dedeakayoğulları and Önal (2009); Ilgar (2009); Külekçi (2009); Özsoy (2009); Artun and Coştu (2011); Cappellaro, Ünal Çoban, Akpınar, Yıldız and Ergin (2011); Çakmak and Gökalp (2011); Arsal (2012); Çankaya (2014); Çakmak, Çakmak and Topal (20180; Yılmaz and Özden (2015). Furthermore, results of the studies for various textbooks carried out by Alkış (2005); Alkış (2006); Dikmenli, Çardak and Öztaş (2009); Para and Ayvaz Reis (2009); Gökmenoğlu (2011); Türköz (2011); Akgümüş (2012); Vinisha and Ramadas (2013); Akgün, Tokur and Duruk (2016); Hussein (2018) confirm these findings.

## CONCLUSION and SUGGESTIONS

The purpose of this study was to disclose the role of water in the units and topics within 9$^{th}$, 10$^{th}$, 11$^{th}$ and 12$^{th}$ grades' biology textbooks that were chosen by the Ministry of National Education (MoNE) Head Council of Education and Morality (HCEM),

In line with this purpose, the findings from the reviewed textbooks have demonstrated that the ratio of the number of units related to the concept of water/total number of units-number of topics/total number of topics are, respectively, 3/3-9/9 for 9$^{th}$ grade, 2/3-8/11 for 10$^{th}$ grade, 3/3-10/12 for 11$^{th}$ grade, and 4/4-8/9 for 12$^{th}$ grade.

The units and topics without the concept of water within the reviewed biology textbooks are 10$^{th}$ grade Unit 1 Topic 3 (growth and development), Unit 2 all topics (genetics and biological diversity, modern genetic practices), 11$^{th}$ grade Unit 2 Topics 1 & 3 (tissues, support and motion system), and 12$^{th}$ grade Unit 1 Topic 1 (discovery and importance of nucleic acids).

The following water-related titles of topics were found to be included in the related textbooks:

"water is important for the living beings"; "water is important for health"; "water plays a role in certain events and biochemical reactions that take place in the living body"; "there are living structures related to water"; "water is a habitat and breeding ground for some living beings"; "water is an energy source"; "there are professional fields related to water"; "water is important on the earth's surface and can be found in various forms"; and "water pollution is a serious environmental issue".

According to the findings, it was concluded that large part of the units and topics in secondary school biology textbooks include the concept of water, and therefore water has a very important place in biology education. In this context, it can be said that biology education is an important tool in conveying the significance of water for the living beings.

Further research can focus on the place of water in teaching other disciplines. It can be researched about the other effective fields of study in conveying the importance of water. Inclusion of water in primary school and secondary school textbooks can also be researched. An in-depth content analysis for the statements regarding water within the textbooks can also be carried out. The content for the concept of water included within the textbooks can be evaluated with a critical approach.

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**APPENDİX-1: Textbooks investigated within the scope of the study**

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# The Application of STEM Education in Science Learning at Schools in Industrial Areas

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## ABSTRACT

The purpose of this research was to measure the effect of STEM-based science learning on Work and Energy topic and students' five entrepreneurial attitudes as a learning outcome. The five entrepreneurial attitudes assessed in this research were (1) self-confidence, (2) initiative, (3) achievement motive, (4) leadership, and (5) risk-taking. This research employed a quantitative post-test design, which was carried out with 219 students from 12 different schools. Before the learning implementation, 24 teachers from the 12 schools collaboratively developed learning materials to be used as the learning source. The validity value of the learning materials assessed by two educational experts was 20 out of 24 and indicated a sufficient validity. A post-test was used to know the effectivity of STEM-based science learning while the five entrepreneurial attitudes were scored with the questionnaires filled by the students. The Likert scale was utilized to analyze the data. The average post-test score was 86 and indicated the students' scores to be in the 'good' category. Additionally, the average scores of the five entrepreneurial attitudes were (1) 85 for self-confidence, (2) 75 for initiative, (3) 84 for achievement motive, (4) 77 for leadership, and (5) 79 for risk-taking. Therefore, the results of this study suggested that the STEM approach was effective to improve the students' entrepreneurial attitudes.

**Keywords:** Entrepreneurial attitudes, industrial area, science, STEM

## INTRODUCTION

STEM stands for science, technology, engineering, and mathematics. As an educational approach, STEM refers to the idea of educating students in those four specific disciplines in an interdisciplinary and applied approach. Rather than teaching the four disciplines as separate and discrete subjects, STEM integrates them into a cohesive learning paradigm based on real-world applications (Bybee, 2010). By exposing students to STEM and giving them

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opportunities to explore STEM-related concepts, they will develop a passion for the STEM concepts and hopefully pursue jobs in STEM fields. A STEM-based curriculum has real-life situations to help students learn. STEM activities provide hands-on and minds-on lessons for students.

Indonesia’s industrial development demands education that can prepare students to have insight into the field of the STEM. The STEM implementation was designed systematically starting from teachers’ knowledge to an entrepreneurship-oriented learning strategy that integrates entrepreneurial concepts in learning materials and activities (Adeyemo, 2009). The application of the STEM in schools is an effort to prepare independent generation through the cultivation of positive attitudes towards the industrial world (Jehopio & Wesonga, 2017).

Researchers in this study conducted a preliminary study in 12 junior high schools with 217 students. The targeted schools were situated in industrial areas. A need analysis was conducted in such schools since there is a variety of uniqueness that affects the students’ way and style of learning. Science was the target learning considering its learning orientation of improving life skills as a part of scientific problem-solving. The prior researchers found that the students learning around industrial areas have unique needs compared to general students. Students are expected to earn life skills drawn from the applied science concepts in each science learning experience (Aikenhead, 2006; Salonen et al., 2017; Marope, 2016; Barron & Darling-Hammond, 2008). Students have a high expectation of science learning as they think that it will equip them with life skills.

Based on the preliminary study performed by the researchers of this study, the students' expectation was inversely proportional to the analysis of learning processes conducted by science teachers in the 12 schools. Given people’s potencies, the observation results showed that their learning was not integrated into life skills. Hence, a lack of technology-oriented concept learning results in undeveloped life skills (Barker et al., 2014; Deveci & Cepni, 2017;Ejiwale, 2012; Mutakinati et al., 2018). Even though science concepts are not limited to the mastery of theories, they should be applicable in practicum. Therefore, they call for a strategy to meet these demands.

The observation results were explored by analyzing the learning tools used in science learning by the teachers in the 12 schools, and it turned out that none of them applied an approach to integrating science and technology. The applied approaches, models, and methods oriented to knowledge transferring in which the outcome was to produce a work could not be achieved through such a learning process. Science learning requires an interdisciplinary approach to relate schools and the working world. Furthermore, STEM is a multidisciplinary approach rehearsing mathematical analysis skills to figure out real problems (Asghar et al., 2012; Breiner et al., 2012; English 2017; Howard & Ifenthaler, 2018; Meyrick, 2011; Sahin, 2015). Students have to be equipped with the STEM understanding and entrepreneurial attitudes to compete in the working world. The STEM approach is required since it integrates schools with the industrial world. Science learning develops knowledge and trains life skills and technology. Therefore, the students should be trained to apply science concepts to create, produce, and maintain.

The schools around industrial areas have been formed by a unique community system. Firstly, factories are built in a particular place, then labors working in the factories slowly create a community which become a settlement. The continuously growing numbers of people around the area establish schools. Students in most industrial schools are laborers’ or workers’ children. The preliminary studies indicated that in the 12 schools, 17% of students dropped out and chose to work in the factories around the schools. The industry tends to hire school-aged people due to relatively low power and wage considerations. Also, students who went to higher levels of education were less than 60%, which means that only about 40% of the students completed primary education.

Geographically, the schools in the industrial area are located within 2 km from the center of industrial activity. This is due to their parents' occupation who are mostly labor. The low level of parental education and people's habits of earning money momentarily to meet the needs have encouraged school-aged children not to go to higher education since they preferred to get a job.

Sociologically, children in industrial areas need a different way of learning science. Hence, in this study, the science teaching materials were developed following the findings of community characteristics by encouraging entrepreneurial-oriented learning. The teaching materials were designed with unique STEM elements. The uniqueness laid in the more straightforward presentation of science concepts and the provision of experience in applying science to the form of simple technology.

Prior to this study, a preliminary observation on this research cite done by the authors found that knowledge-oriented learning was not sufficient for the students around industrial areas. They needed working skill obtained from learning. The ability, on the other side, was required to prevent them from dropping out and equip dropped-out students with basic entrepreneurial skills by integrating the STEM concepts in learning. The science learning integrated with entrepreneurial skills formed the students' entrepreneurial attitudes and supplies business knowledge to the students as an implementation of science learning. Through the STEM approach, it was expected that the students could make use of the opportunities around them as business opportunities. Therefore, the teachers had to develop the STEM-based learning tools that would improve the students' entrepreneurial attitudes. All STEM elements were integrated with the learning process resulting in essential knowledge (English 2016; Kelley & Knowles, 2016; Shernoff et al., 2017; Torlakson, 2014). Furthermore, Brown et al. (2011) stated that science is a knowledge of concept and law; technology is a skill or a system used to design and utilize an artificial tool that can facilitate human work; engineering is the knowledge to operate a procedure to solve problems; and mathematics is a discipline in connecting the quantities, numbers, and spaces that requires only logical arguments without or accompanied by empirical evidence.

This research was essential in considering the growth of industrial areas resulting in the increasing number of students in the regions who had practical ways of thinking. In implementing the STEM approach, science learning should be designed under the impacts on students' entrepreneurial attitudes in industrial areas. The findings of prior studies indicated that students were affected by the region and through science learning; experiences would be obtained by students to develop business-valued work. Learning scenario needed to be set to grant entrepreneurship experiences for students. Learning environments should be designed to provide real experiences for students to grasp the importance of entrepreneurs (Alkan, 2016; Pittaway & Cope, 2007). Also, Vennix et al. (2017) found that students' perception of the STEM learning benefits required being facilitated through concrete learning activities so that their expectations can come true. The integration of four STEM elements gave opportunities to raise the entrepreneurial spirit. Lee and Erdogan (2007) explained that the effect of the integration between science and technology in learning was to convince the students about the importance of science learning.

Strengthening the importance of this research, the analysis of the previous studies' results on STEM learning has been proven to change the old habits that focused more on knowledge-transferring into a new, work-oriented way of learning (Basham & Marino, 2013; DeSutter & Stieff, 2017; Edwards et al., 2015). The implementation of the STEM has the potential to change the teachers' habits in using noncomplex approaches by taking into account the demand for integration with other elements. The impact analysis of the previous researchers showed that the implementation of the STEM had the potential to reinforce the students' entrepreneurial attitudes which were not linked yet in the lesson. The previous researchers also figured out that teachers considered the STEM approach as a difficult one since it has to be integrated with many elements. Table 1 presents the integration of entrepreneurial attitudes into the STEM approach.

**Table 1.** *The Integration of entrepreneurial attitudes into the STEM approach*

| STEM Approach | Entrepreneurial Attitudes |
|---|---|
| **Science.** The skill in applying knowledge and science process in understanding natural phenomena and manipulating the phenomena so that it can be implemented. | Students' self-confidence toward their knowledge. |
| **Technology.** The skill in knowing the technology that can be developed and its usage in facilitating human work. | Taking the initiative to provide an idea of the technology form used in facilitating community work around the school. |
| **Engineering.** The skill in utilizing technology to create a useful way. | Designing beneficial products. |
| **Mathematics.** The skill in solving problems based on the calculation of mathematics data. | Being courageous in solving problems by applying the calculation of mathematics data. |

The purpose of this research was to measure students' five entrepreneurial attitudes as the outcomes of STEM-based science learning. Therefore, this study was a part of the STEM approach habituation in science learning as a solution to the gap between schools in industrial areas and social demands. Figure 1 presents the theoretical framework of this STEM approach towards the students' entrepreneurial attitudes at schools in the industrial areas.

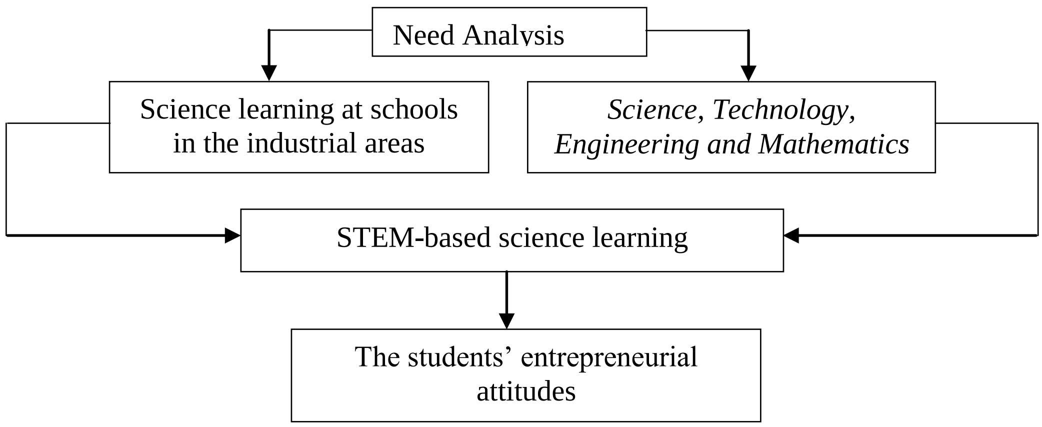


***Figure 1.*** Theoretical Framework

The learning approach was designed based on the literature review and theories explained in the preliminary study. The need analysis indicated that there were gaps between students' expectation and reality in science learning at schools in the industrial areas. Therefore, a solution was proposed; the adoption of the STEM approach integrated with the science concepts and technology.

As a learning approach, the STEM is likely to cultivate students' entrepreneurship sense (Adlim et al., 2015; Syukri et al., 2013). The impact of the STEM approach on students' entrepreneurial attitudes in industrial schools was the focus of this study. Teachers taught the material contextually according to the needs of students. The results of this study can be an essential part of synergizing science learning, schools, and community demands. The application of this approach was an effort to prepare responsive students to the needs and desires of the development of science and technology. The participants of this research were 14-16 years-old students. Thus, the entrepreneurial spirit used in this research was at the level of entrepreneurial attitudes, not at the real entrepreneurial activities. The aspects of entrepreneurial attitudes measured in this study were limited to five points including self-confidence, initiative, achievement motive, leadership, and risk-taking.

## METHODS

The research was carried out at schools in the industrial areas; one of the schools in this study was the SMP 01 Sayung in Central Java which is located in the industrial area of Semarang City. Geographically, the location of the school is shown in Figure 2.


***Figure 2.*** The School in the İndustrial Area (https://jatengproperty.com)

A quantitative post-post design has been adopted in this study. The sample was 219 seventh grade students from 12 different schools chosen using a random sampling technique. There were 24 science teachers (i.e., two teachers from each school) participated in this study. The research lasted in 12 weeks consisting of several stages as follows: (1) preparation of learning tools (1st-4th week); (2) validation of learning tools (5th week); (3) learning implementation (6th-10th week); (4) data analysis (11th-12th week).

All the 24 teachers in this study acted as the developer who worked collaboratively to construct the STEM-based learning materials under the researchers' supervision. All teachers taking part in this study had been trained specifically to make and apply the STEM approach in learning materials on Work and Energy topic. A preliminary training was carried out to the teachers in constructing the desired learning materials which referred to the modified ADDIE model proposed by Welty (2008) having the following stages: (1) Analysis of the existed learning materials; (2) Designing learning materials on Work and Energy topic; (3) Integrating STEM into the learning materials; (4) Validation of learning materials; (5) Learning implementation. Two educational experts tested the learning materials' validity and reliability referring to Arikunto (2012). There were six points assessed by the validators of the learning materials including(1) Materials immensity, (2) Concept authenticity, (3) Linkage of scientific process to understand natural phenomena, (4) Adaptation of modest, applicable technology, (5) Suitability of the industrial environment, and (6) Adaptation of mathematical calculation in solving problems.

The core stages of the Work and Energy topic integrated with STEM adopted to the Presentation-Practice-Production (PPP) structure for science learning (Criado, 2013). In the Presentation stage (6th week), the teachers presented the industrial activities found around the school environment and their link with STEM. In the Practice stage (7th-8th week), the students designed a modest product to implement STEM in the Work and Energy topic. In the Production stage (9th-10th week), the students produced the intended products (i.e., game tools and props from recycled materials).

Following the learning implementation in each school, a post-test was performed to reveal the students' mastery level on the targeted topic that also reflected the effectivity of the developed learning materials. There were 30 items in the post-test that were identified as valid and reliable. The validity was tested using Product Moment correlation (Aktamis & Ergin, 2008) by calculating the correlation coefficient between the scores of each item with a total score. The rxy price obtained was consulted with r table of 5% product moment. The significant level was α 5%. When the value of r count had a greater value than r table product moment, the items were considered as valid. Also, to get trusted instruments, the reliability was examined. This reliability test was carried out in the population using the Cronbach Alpha formula (Taber, 2018). The value of r obtained was consulted with the product moment table with an error rate of 5%. Whenthe value of r was found greater than r table product moment,the instrument was considered as reliable. The post-test criteria are presented in Table 2.

**Table 2.** *The Post-test Criteria*

| Score Range | Category |
|---|---|
| ≥ 80 | Very high |
| 60-79 | High |
| 40-59 | Fair |
| 20-39 | Low |
| <20 | Very low |

(Adapted from Aqib, 2009, p. 41)

The researchers collected the data of (1) the effectivity of STEM-based science learning on Work and Energy topic via post-test and (2) the measurement of the students' five entrepreneurial attitudes as a result of the STEM-based science learning via questionnaires filled by the teachers. The teaching materials were integrated with STEM, compiled by the teachers, validated by two experts who were lecturers with expertise in the field of science teaching materials development and entrepreneurship course.

Furthermore, the students' entrepreneurial attitudes were measured using questionnaires. There were five indicators of entrepreneurial attitudes consisting of three items in each indicator and 15 items in total. Before questionnaire distribution, a reliability test was performed by comparing the Cronbach alpha values. If the value obtained is higher than 0.60, then the instrument is said to be reliable (Taber, 2018). The result of the reliability test showed a score of 0.62; thus, it indicated that the instrument is reliable.

## FINDINGS

### a) Validity and Reliability of Learning Materials

Table 3 shows the validation results of science materials that experts developed with the STEM-based science learning approach.

**Table 3.** *The validation results of STEM-based science learning materials*

| Teaching Materials Aspects | Score | Category |
|---|---|---|
| Materials immensity | 4 | Very Good |
| Concept authenticity | 4 | Very Good |
| Linkage of scientific process to understand natural phenomena | 3 | Good |
| Adaptation of modest, applicable technology | 3 | Good |
| Suitability of the industrial environment | 3 | Good |
| Adaptation of mathematical calculation in solving problems | 3 | Good |

The validity score of the learning materials was obtained by collecting the number of validators' answer scores and compared with the maximum number of scores. The score obtained was 20 out of 24, therefore, the validity score was 83 which meant that the learning materials were worthy of use. The assessment aspects of the teaching materials measured the four STEM elements that were in 'good' categories. Furthermore, the teaching materials used in the learning process integrated the four STEM elements.

### b) Validity and Reliability of Post-test Items

Based on the calculation of validity, we obtained 15 questions that had $r_{count}$ value higher than $r_{table}$ value. Moreover, the analysis of question reliability at $\alpha = 5\%$ with 15 questions, we obtained $r_{11}$ value of 0.65 while found $r_{table}$ value as 0.46. Since the $r_{11}$value was greater than $r_{table}$ value, we concluded that the instrument was reliable.

### c) The Effectivity of STEM-based Science Learning Materials on the Students' Mastery Learning

Students worked on a post-test after finishing the learning on the 10th week. The number of items was 30 in the post-test. The questions were not onlyabout mastery of the content but also include the students' understanding of the application of material on products. The results of the 219 students' post-test scores in 12 schools can be seenin Figure 3.

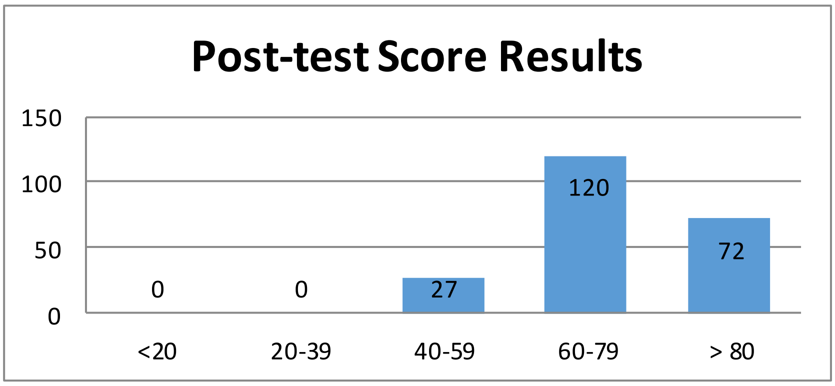


***Figure 3.*** The Post-test Results of STEM-based Science Learning

As seen in Figure 3, most of the students had a good mastery of the material. The number of students who scored between 60 and 79 was 120 and were in the 'high'category, and 72 students who scored higher than 80 and fell in the 'very high' category. These results suggest that the STEM-based science learning materials were effective in helping the students' mastery of the Work and Energy topic.

**d) The Effectivity of STEM-based Science Learning Materials on the Students' Entrepreneurial Attitudes**

Students' entrepreneurial attitudes were scored during the learning activities. Figure 4 presents the results of the students' five entrepreneurial attitudes as the impact of the STEM-based science learning.

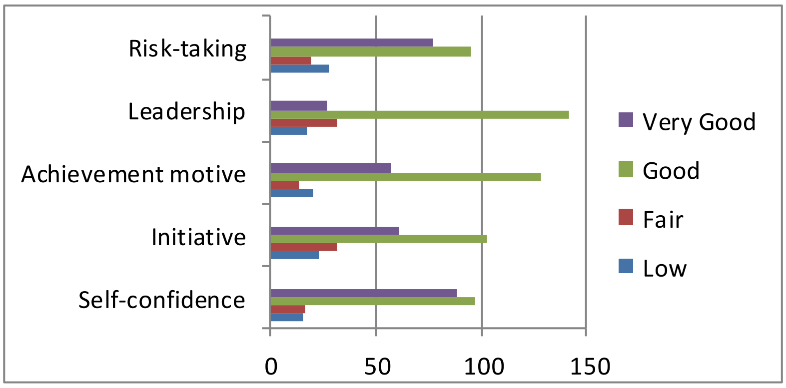


**Figure 4.** *Students' Entrepreneurial Attitude after STEM-based Science Learning*

All 219 students' entrepreneurial attitudes in this study were the outcomes of STEM-based learning. The measured five entrepreneurial attitudes revealed that 76.08% of students had 'good' and 21.05% of students had 'very good' entrepreneurial attitudes. The data analysis performed on each student for the five aspects is presented in Figure 5.

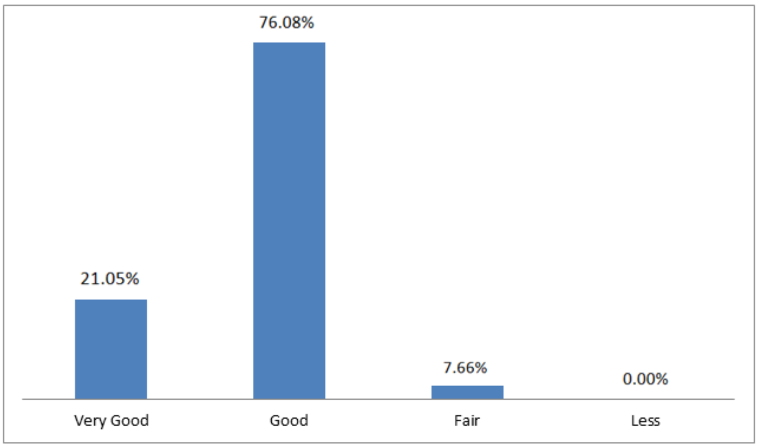


**Figure 5.** *The Category Percentage of Students' Entrepreneurial Attitudes as the Impact of STEM Approach Application*

The learning activities integrated with entrepreneurship values in science learning shaped the students' entrepreneurial attitudes. The implementation of this approach gave students space to produce work based on their understanding of science content. Seen from the learning activities carried out, the students expressed high interest in science. The students also indicated that they could gain new perceptions by learning science, new skills as the outcomes of their science applications.

## DISCUSSION and CONCLUSION

The scientific process that the students involved in this research emphasized the work skills. Science has been studied to understand and manipulate natural phenomena. Results of this study suggested that 84% or 186 students showed a high self-confidence, which meant that the learned science could be used to understand the natural phenomena. Science remains the most critical part of the application of the STEM since it is the studied knowledge. The students employed science to identify forms of technology that could be developed in designing and creating products as the learning outcomes and science learning was used to create technology in fulfilling human needs (Çinar et al., 2016; Fainholc, 2010; William, 2018; Yıldırım & Sidekli, 2018).

Moreover, the study carried out by Guzey et al. (2017) found that science learning is not always oriented to high technology but ways to integrate science in daily life. High self-confidence is essential for the students to take the initiative to convey ideas of the technology form used to facilitate work. The students living around the industrial area tended to think practically. They would connect what they learned to the real life of what their parents do. Thus, they would be motivated to acquire science concepts taught explicatively by the teachers.

The students who were courageous to take the initiative during the lessons were 75% or 164 students. They were coming up with the ideas of product design such as making green juice, making a cricket cage, and making a rug patchwork. The concept of the green juice emerged after the students learned about the concept of human digestion system, while the cage cricket idea appeared after discussions about insects, and the concept of the rug patchwork came up after the students learned about groundwater absorption. The designed technology was elementary, yet become an essential part of fostering the students' creativity. No matter how small the creativity of students in producing a product of science learning was, it was an exciting experience for them (Annetta et al., 2013; Deveci, 2018; Madden & Dell'armo, 2016). The students' initiatives were the sign of favorable concept mastery. This research elucidated that the STEM approach fostered the students' ability to create practical product designs. The science teacher adopted basic mathematical calculation in explaining a product; therefore, the students acquired the importance of mathematical calculation. Moreover, the students' ability to design a product indicatedthe significance of technical knowledge they earned through science learning.

Designing such simple work, at least, described the skills gained through science learning. The engineering element in the STEM was measured by the skills in utilizing technology to design a beneficial way. The students designed products by their understanding of science. The STEM's excellence were observed in this study can be seen from how the teachers encouraged the students in trying to design products resulting in generating various designs. Dinatha (2017) stated that not all students could produce a work based on science learning. In fact, by implementing the STEM, the activity becomes indisputable. Designing skills that students have is a benchmark of their concept mastery. These research findings strengthened that conceptual knowledge is not sufficient but the skills acquired after mastering the integration of science and mathematical concepts.

Developing products is a form of training for students in solving problems. The mathematical element in this approach emphasized the students' courage to solve problems by applying the calculations and mathematical data according to the learned science concepts. More than 75% of the students in the industrial areas were confident to take the risk through science learning andcould cultivate the leadership needed as one of the entrepreneurial attitudes. Aguilera and Perales (2018) elucidated that learning science could not be separated by the character building and courage. The scientific courage means the students' decision in taking action on a specific problem given by the teacher during the science learning. According to these research findings, the STEM approach was able to provide a new way of learning science to the students since it was beneficial in raising critical thinking.

The students' five entrepreneurial attitudes were measured as the impact of STEM-based science learning. The students' positive attitudes in science learning were needed to have a stronger encouragement towards science. This is parallel to a previous study by Aguilera and Perales (2018) who stated that students' attitude in learning science is determined from the learning activities during the knowledge-transferring process of science. As found in the preliminary studies, students in industrial areas have a simple way of thinking about "What I got from learning science." The result showed 76.08% of students had a right attitude towards science learning, which was integrated with all STEM elements. The students experienced in producing works of studied knowledge and developing entrepreneurial attitudes, which was impossible to have without real activities. The students interpreted entrepreneurship as activities to provide something like the results of school learning.

The application of the STEM approach in science learning to 219 students in 12 junior high schools geographically located in industrial areas enabled students to develop entrepreneurial attitudes. Results showed that 76.08% of the students were in the 'good' category while others (i.e., 21.05%) were in 'very good' category according to the analysis results of five entrepreneurial attitudes including confidence, initiative, achievement motive, leadership, and risk-taking. The entrepreneurial attitudes acquired by the students after gaining the knowledge in designing products during the science learning.

## Suggestions

STEM Education has been a worldwide interdisciplinary approach that coupled with real-world lessons in contexts to make connections among school, community, work, and the global enterprise, particularly to prepare students in facing the 21st-century challenges. This fact underlies this research in which junior high school students were equipped with multidisciplinary knowledge packed in science learnings. Nevertheless, teaching using the STEM approach is far different from teaching how to perform scientific works as such a method tries to raise entrepreneurial skills among students. Consequently, teachers should allocate extra time and intensive effort to prepare and teach using the STEM approach.

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