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The Effectiveness of STEM-Based on Gender Differences: The Impact of Physics Concept Understanding

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Abstract: The purpose of this research is to describe the effectiveness of STEM on the physics concepts understanding seen from gender differences. The research method used is a type of quasi-experimental design with 2x2 factorial design and saturated sampling technique. The data collecting technique used a tested method to see the results of students' concept understanding. Hypothesis testing was done using two-way ANOVA 2 x 2 factorial designs. The results of the study are: (1) there are differences in STEM and conventional learning on concepts understanding and the use of STEM learning is more effective than the conventional one; (2) there are differences in the results of understanding the concept between male and female students where male students are higher than female students; and, (3) there is no interaction between learning and gender towards concepts understanding. The research recommends designing the STEM-integrated ESciT learning to be relevant with the indicator measurements and to manage the learning effectively to obtain optimum learning outcome.

Keywords: *ESciT, STEM, gender differences, understanding concepts.*

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Introduction

Learning in the 21st century requires integration of learning with the daily life processes. One of the alternatives is to integrate several fields into STEM learning (Science, Technology, Engineering, and Mathematics). STEM is a field that requires numeracy, understanding and analyzing empirical data including critical analysis; understanding of scientific and mathematical principles (Ernst, Williams, Clark, Kelly, & Sutton, 2018; Vulperhorst, Wessels, Bakker, & Akkerman, 2018). Not only that, STEM requires students to apply a systematic and critical assessment of complex problems with an emphasis on theoretical knowledge from the subject to practical problems, ingenuity, logical reasoning and practical intelligence (Mutakinati, Anwari, & Yoshisuke, 2018; Sanchis-Segura, Aguirre, Cruz-Gómez, Solozano, & Forn, 2018).

The understanding and scope of STEM skills vary greatly in various countries (Ernst et al., 2018; Vulperhorst et al., 2018). Supply is relatively clearly identified in terms of qualifications achieved in STEM subjects, although the definition of STEM subjects can vary (Fitzakerley, Michlin, Paton, & Dubinsky, 2013). STEM score subjects usually include mathematics; chemistry; computer science; biology; physics; architecture, civil engineering, electricity, electronics, communication, mechanics, and chemical engineering (Stoet & Geary, 2018).

Problems arise in several gender-related countries of workers (Han, 2016; Sanchis-Segura et al., 2018; Stoet & Geary, 2018). Many large companies in the field of engineering need male workers, but not a few need female workers (Sanchis-Segura et al., 2018) because female workers are generally very thorough at work. Gender differences in career

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interests also contribute to women's underrepresentation in mathematics-intensive fields (Pitan & Atiku, 2017; Williams & Mangan, 2016).

A meta-analysis shows that men prefer to work with objects, while women prefer to work with other people (Mccullough, 2011). Women's preferences for socially oriented work can be motivated by altruism since women possess greater desires than men to help others and to benefit society (Cedefop for the European Commission, 2014). STEM careers are often considered to be inconsistent with common goals which make many women ignore STEM. Even in the STEM field, women are more likely to choose the field that emphasizes community or people-oriented (Vennix, den Brok, & Taconis, 2018). Women, for example, obtain degrees in biomedical engineering and the environment at a higher level than mechanical or electrical engineering (Stoet & Geary, 2018). This evidence shows that preferences may exceed abilities, even among women who choose careers at STEM (Hill, Corbett, & St Rose, 2010).

The result of a study conducted by Catherine et al. at AAUW, nearly one-third of the new students, consisted of men (29%) and only 15% of female new students who planned to major in STEM in 2006 (Figure 1). Gender disparities in choosing the majors are even more significant when biology is not included. More than a fifth of male new students plan to take up engineering, computer science, or physics compared to only about 5 percent of female new students. Women who involve in the STEM field in college tend to be of good quality (Hurk, Meelissen, & van Langen, 2019). In the STEM field, women and men in the first year were equally likely to have taken high grades in math and science classes because they had confidence in their mathematical and scientific abilities (Stoet & Geary, 2019).

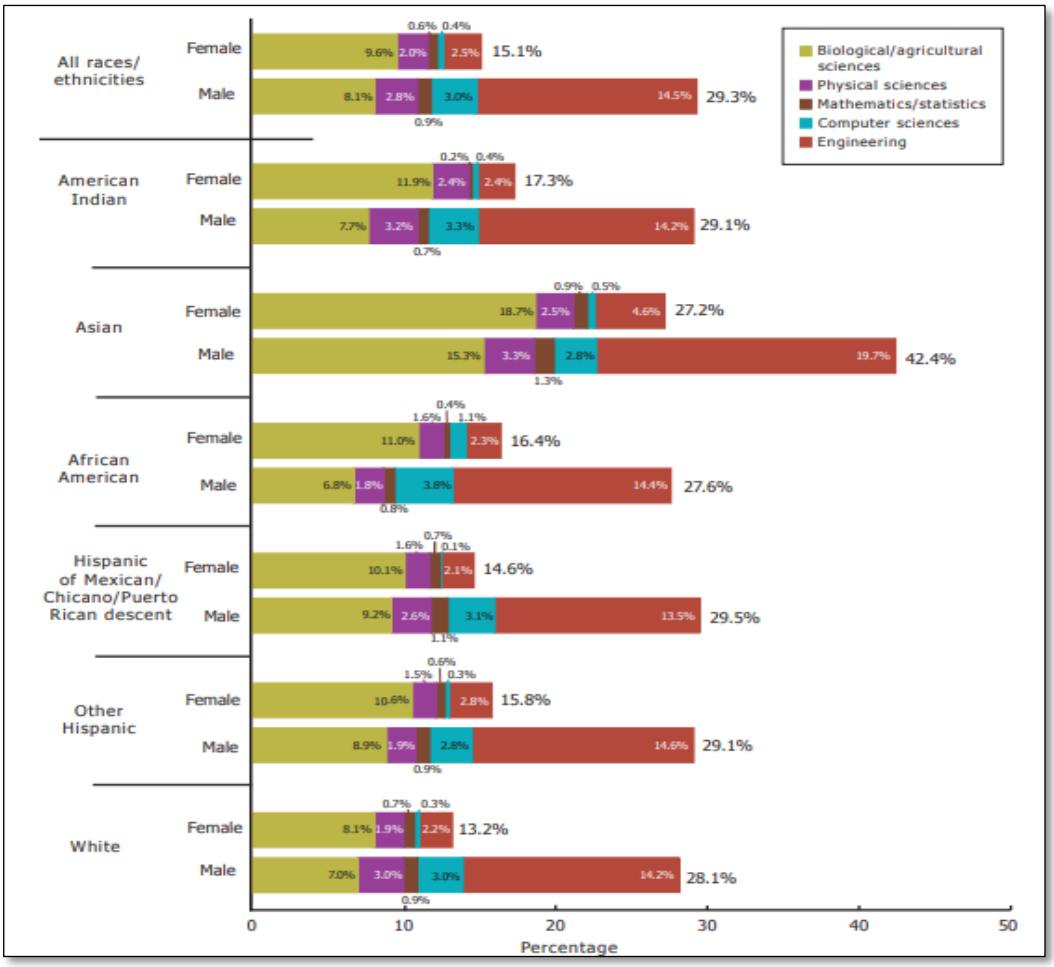

Figure 1. The First Year College Students to Major in STEM Fields between Ethnicity and Gender (Hill et al., 2010).

Figure 1 shows that there are various races (American, Indian, Asian, African, American, Hispanic, and non-Hispanic). Male prefer engineering, physics, mathematics, and technology compared to female. While female prefer biology. Basically, all these fields have a very close relationship. STEM is one of the learning solutions in integrating several of these fields.

STEM education provides opportunities for teachers to show and practice the concepts, principles, and techniques of science, technology, engineering, and mathematics that can be used in an integrated manner (DeCoito, 2016; Irwandani & Rofiah, 2015; Irwansyah, Sukarmin, & Harjana, 2018; Ritz & Fan, 2015). Thus, STEM learning provides real output for age development, including computational thinking with the development of comparative thinking that facilitates the

people to send data quickly (Syukri, Lilia, & Subahan, 2013). *The mentioned matters cause 4.0 industrial revolution became the talk of the people in various worlds (Anwar, Saregar, Hasanah, & Widayanti, 2018; Saregar et al., 2018), including Indonesia. There are several skills that must be possessed to face the current industrial revolution, namely concepts understanding, which is included in the cognitive abilities (Anwar et al., 2019).*

The success of concepts understanding is influenced by several factors; one of which is the use of learning approaches (Abdurrahman, Saregar, & Umam, 2018; Rusmana, 2014). *The approach that follows the development of the 21st century is STEM learning (Permanasari, 2016).*

Learning using STEM (Science, Technology, Engineering, and Mathematics) can be integrated with a flexible learning model that can foster students' knowledge (Lestari, Saryantono, Syazali, Jauhariyah, & Umam, 2019), create solutions to solve problems that change rapidly in the future (Tsai, Chung, & Lou, 2018), and become a key in creating the next generation of the nation that is globally competitive in order to become a reference in the future process of Indonesian education (Firman, 2016).

Based on previous research, STEM is able to train students to think critically (Syukri et al., 2013) *and creatively (Ismayani, 2016) which is included in the function of applying 4C in the industrial revolution (Mukti, 2018). Learning using STEM can increase the effectiveness of learning and can support a career in the future* (Tseng, 2011).

Classroom learning has very diverse success rates between male and female students. So that there are differences in the results of learning between genders that have differences in terms of psychological or physiological. A previous research report shows that the learning outcomes of male students were higher than female students (Pusfarini, 2017; Wahyudi, 2014) and the scientific literacy between male and female students does not have a significant difference between the two (Afriana, Permanasari, & Fitriani, 2016).

The difference between this research and the previous research lies in gender as a point of view to see the concept understanding in STEM learning. This study aims to see the concepts understanding between genders by applying the STEM learning approach.

Method

Research Goal

The difference between this research and the previous research lies in gender as a point of view to see the concept understanding in STEM learning. This study aims to see the concepts understanding between genders by applying the STEM learning approach.

Sample and Data Collection

The research method used was a type of quasi-experimental design with a 2 x 2 factorial design. The population used was the eleventh-grade science students of SMAN (State Senior High School) 1 Katibung, Lampung. The sampling technique used was saturated sampling where the eleventh-grade science one students were taught using ESciT (Entrepreneurial Science Thinking) integrated STEM, and the eleventh-grade science two students were taught using conventional learning. ESciT is one of the learning to produce students with entrepreneurial thinking. By integrating it with STEM, it is hoped that it will support better science thinking with maximum skills output. Conventional learning was done in this study by using learning that is commonly used by the teachers in the learning process. The number of students taught using STEM- integrated ESciT learning were 36 students (13 male students and 23 female students) and the number of students taught using conventional learning were 34 students (13 male students and 21 female students). Students who were the sample in this research were around the age of 16-19 years.

Analyzing the Data

Data collecting techniques used tested method to see students' understanding of concepts and interview method to see the problems that occur in learning. Before the analysis was carried out, the normality test and homogeneity test were carried out. The statistical test used a significance level of 5%. Hypothesis testing was carried out using a two-way ANOVA test with a 2 x 2 factorial design assisted by SPSS 17 program.

Findings

The research data includes the data of concept understanding tests. Table 1 contains the scores of concepts understanding based on learning, and table 2 contains the scores of concept understanding based on gender.

***Table 1**. The Score of Concepts Understanding Based on Learning*

Learning Approach	Total of data	Average Score	The highest score
STEM	36	68,75	87
Conventional	34	64,44	77

Table 1 shows that the average score of the concept understanding test of using ESciT integrated STEM is higher than the conventional one. Furthermore, the highest score of ESciT integrated STEM learning is higher than conventional learning.

Table 2. The Score of Concepts understanding Based on gender

Gender	Total of data	Average Score	The highest score
Male	26	70,77	87
Female	44	64,50	87

Table 2 shows that the average score of the concept understanding test of male students is higher than female students. Furthermore, the highest score between male and female students is the same. The analysis of prerequisite tests was done using the Shapiro-Wilk formula for the normality test, and homogeneity test was done using homogeneity of variance test assisted by SPSS 17 program with a significance level of 5%. The following tables show the results of the normality and homogeneity test data.

***Table 3**. The Results of the Normality Test*

Concepts	Group	Sig	Information
Understanding	Experiment	0,274	Normal
	Control	0,072	Normal
	Male	0,550	Normal
	Female	0,133	Normal

Table 3 shows the data of the concepts understanding of both the experimental and control class was normally distributed. Both male and female students were also normally distributed. This was done to determine the data analysis used in this research.

***Table 4**. The Results of the Homogeneity Test*

Concepts	Group	Sig	Information
Understanding	Experiment	0,147	Homogeneous
	Control		
	Male	0,667	Homogeneous
	Female		

Table 4 shows the data analysis of the concepts understanding of the experimental class and the control class was homogeneous. The male and female were also homogeneous. This was done to determine the analysis of the data used in this study. Based on the results of these data, the data were normally distributed and had homogeneous variance. The hypothesis testing of the data using two-way ANOVA with the 2x2 factorial design was done using the SPSS program.

Table 5. The Hypothesis Test Results

No	Two-way ANOVA Hypothesis	Significance of Concept Understanding	Test Result
1	Approach	0,002 < 0,05	H_0 is rejected
2	Gender	0,001 < 0,05	H_0 is rejected
3	Interaction	0,397 > 0,05	H_0 is accepted

The overall pattern of interaction of hypotheses is shown in Figure 2.

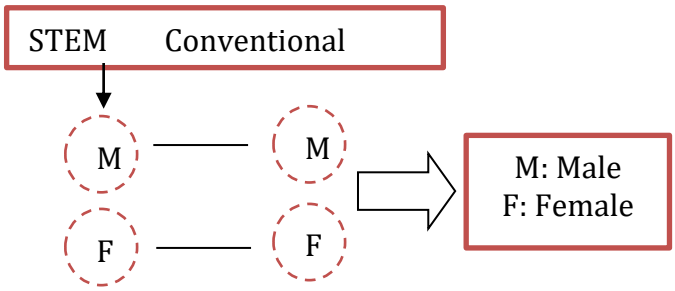

Figure 2. The Overall Pattern of Hypothesis

The first hypothesis

The first hypothesis is the ESciT integrated STEM and conventional approaches toward concept understanding. The pattern of the first hypothesis in this study is presented in Fig. 3,

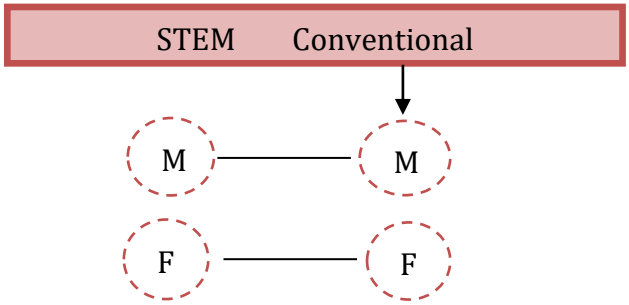

Figure 3. The Pattern of the First Hypothesis

Figure 3 shows that the first hypothesis in this study looked at the effect of STEM-integrated ESciT learning and conventional learning in understanding concepts seen from male and female gender in each learning. The researcher explained the learning steps when doing the learning process. The procedure of ESciT Integrated STEM,

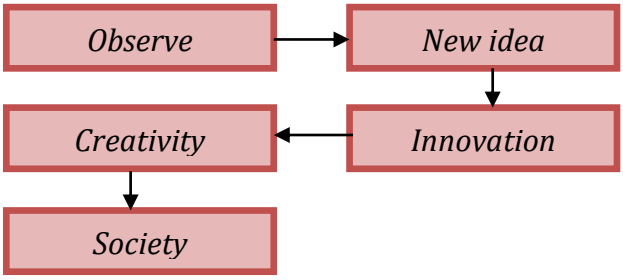

Figure 4. The procedure of ESciT Integrated STEM

ESciT integrated STEM was applied to the learning process using PhET simulation, students are assisted by the teacher to observe phenomena that occur in everyday life and help them to observe experiments using PhET simulation. This step is the first step, namely, observation. Students are directed and guided by the researchers to observe and see the worksheet.

Discussion and Conclusion

Learners discuss with each other to answer the questions on the worksheet according to the steps in learning. This step is the second to the fifth step in learning, namely new ideas where the students get information or new things from what has been observed and trained to be proficient in analyzing and thinking critically (Syukri et al., 2013). This is in accordance with the research from (Chein & Lajium, 2016) that says the STEM approach could improve students' thinking skills so that students are trained to understand the concept by thinking critically.

The innovation step is where the students describe new ideas by understanding experiments and answering questions according to their abilities and knowledge. The creation step is where the students apply their understanding to the concept by collecting the results of experimental data. Students are also asked to design a spring prop and answer questions related to the material mathematically. Students try to create observations with their ideas as outlined in worksheets and to design spring props that can be applied in learning and daily life.

This is in accordance with research by (Ismayani, 2016) that claims the STEM approach could improve students' creative thinking skills. The last step is to draw conclusions related to daily life and makes spring props. This can help the students mastering the lesson by not only understanding the material but can apply it in daily life.

The situation is quite different in the control class that uses conventional learning. The researchers explain the purpose of learning and provide apperception on the elasticity and law of Hooke material. Furthermore, students are given the opportunity to read books on the material and are given the opportunity to ask researchers about the things they read. Next, the students work on the worksheet and presenting the results of the discussion.

Learning using conventional learning makes the students rarely active in initial knowledge and lack of motivation at the beginning of learning. When students are conducting experiments or solving questions on a worksheet only solely to complete the task without understanding the material. So students are lacking in knowledge that has an impact on the learning process and low understanding.

The conclusion shows that there are differences between ESciT integrated STEM and conventional learning. It can be concluded that ESciT integrated STEM is more effective, although not significant compared to conventional learning. Understanding the experimental concept using ESciT integrated STEM is higher than the conventional learning in the control class. This result is relevant with research conducted by (Tseng, 2011) who states that STEM learning with practicum can provide a real learning experience, can improve the effectiveness of learning, and can support careers and professions in the future. So that by using STEM learning, the students not only get the material, but there are practices for students in the learning process.

The second hypothesis

The second hypothesis is the group of male students and the group of female students towards concept understanding. The pattern of the second hypothesis in this study is shown in Figure 5.

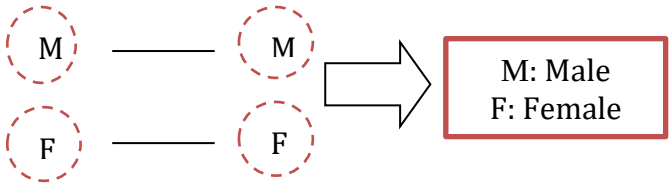

Figure 5. The pattern of the Second Hypothesis

Based on table 2, the average score of male students is 70.77, and the female students are 64.50. So that male students are better in understanding the concepts than the female students. This shows that gender differences between male and female in concepts understanding are a concern in learning.

Research conducted by (Nuyami, Suastra, & Sadia, 2014) shows that gender differences affect the level of understanding of students as found in the research using inquiry learning methods to improve student understanding. Based on the results of the average score of concept understanding between male and female students, the male students have a higher average score than the female students based on table 2.

According to (Wahyudi, 2014), "the female left brain is more developed than the male left brain." So that in science learning, male students are more successful since they are using the right brain where male learners learn in terms of practice compared to female students who tend to be good in terms of theory.

In STEM learning, there are creative steps that make male students excited and enthusiastic in the learning process rather than conventional learning. Gender differences have an influence on the learning outcomes based on their learning styles, in fact, male students prefer the learning process that is practical compared to just the theory. So that there are differences in learning outcomes between male and female students. Therefore, male students have slightly higher achievement in science learning compared to female students.

This is in accordance with the research conducted by (Wahyudi, 2014) which concluded that women have more control over health and environmental issues while men are more mastered and superior in physics, mathematics, and chemistry. That way, there are gender differences in science learning.

This study is relevant to the one conducted by (Afriana et al., 2016), who says that the score of n-gain in the male class is higher than the female class using STEM learning. It can be concluded that in STEM learning, the male students are more energetic and motivated. In fact, male students are less attentive and less enthusiastic in the learning process.

The Third Hypothesis

The third hypothesis test is that there is no interaction between learning and gender towards concepts understanding. The ESciT integrated STEM and conventional learning that uses scientific learning have relatively good results towards concepts understanding seen from gender.

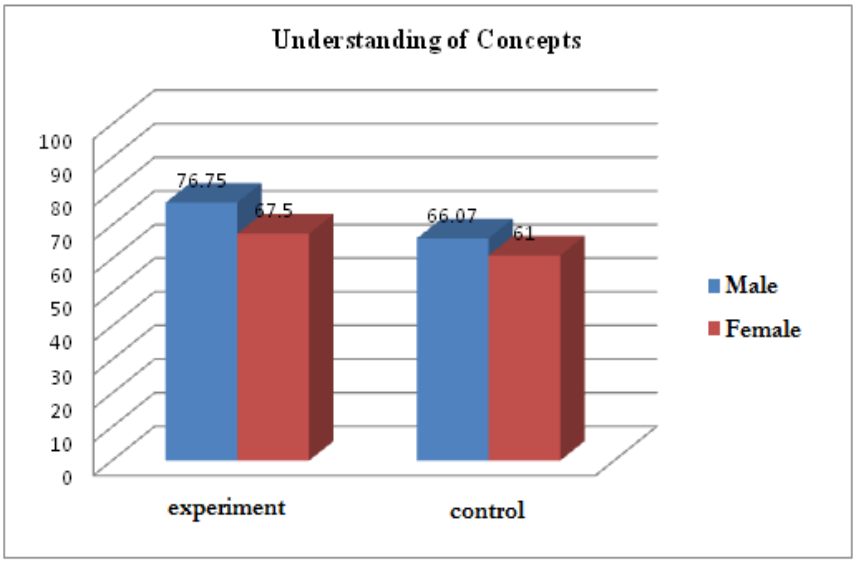

Figure 6. The Results of Concepts Understanding of the Experimental and Control Classes Seen from Gender

This can also be seen in figure 6, which shows an average score that is almost relatively the same. STEM learning does not have a significant effect on conceptual understanding. This research similar to the one conducted by (Dupri & Abduljabar, 2015), who states that there is no significance between learning and gender. The male and female students can learn well using STEM and conventional learning.

The learning process that can influence the understanding of the concept is influenced by the teachers' approaches. Learning that is influenced by gender differences can make students in ESciT integrated STEM learning more active and creative than conventional learning. However, it appears that there is no connection or relationship between learning approaches and gender differences in concepts understanding. The findings do not meet the results of the study may be that students are less serious during the learning process and the poor class management that disturbs the students' concentration.

Based on the findings and discussion, several conclusions are obtained, among others: (1) STEM-integrated ESciT learning is better than conventional learning. This is because STEM-integrated ESciT learning prioritizes learning that provides good output skills. (2) Gender differences in male students are better than female students in understanding concepts. This is because men have more concepts based on events that occur while women have more theoretical concepts. (3) there is no interaction between learners and gender, however, in this study, it was found that the use of STEM was more effective in the learning process and concepts understanding in male students rather than women.

Recommendations

Further research is recommended to use ESciT integrated STEM when the learning process takes place. In addition, it is necessary to design STEM-integrated ESciT learning in accordance with the measurement indicators maximally. The teachers should pay more attention to time management and how to direct the students so that the time is not used up when the learning process takes place.

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