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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.

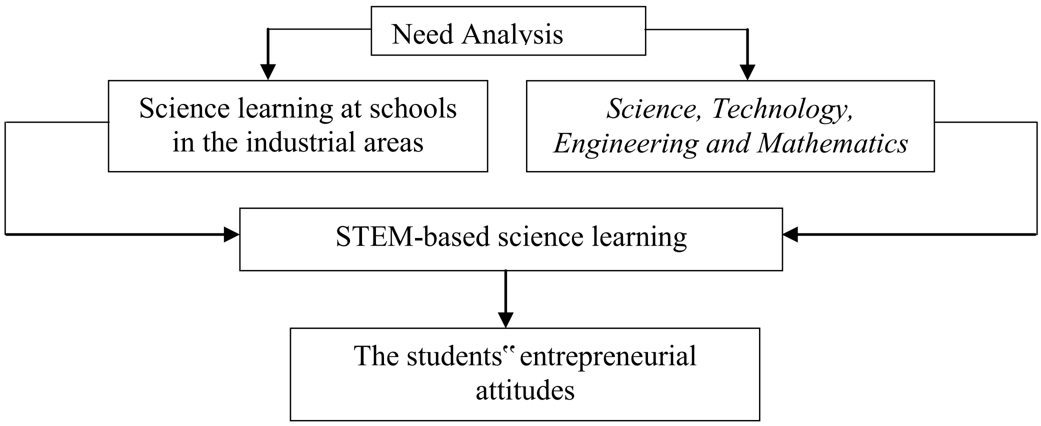

Figure 1. Theoretical Framework

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.

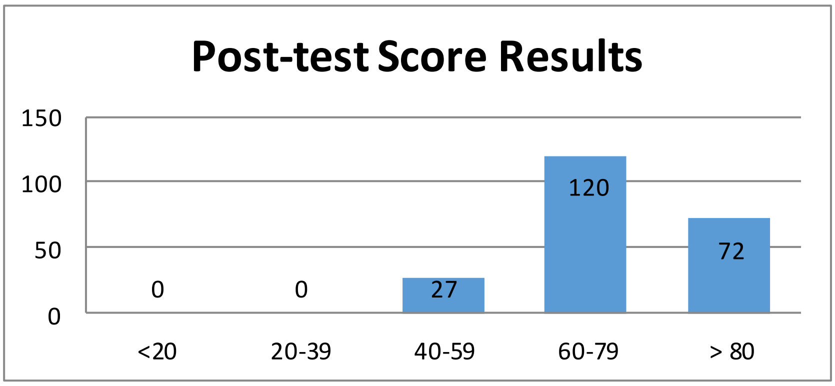

Figure 3. The Post-test Results of STEM-based Science Learning

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.

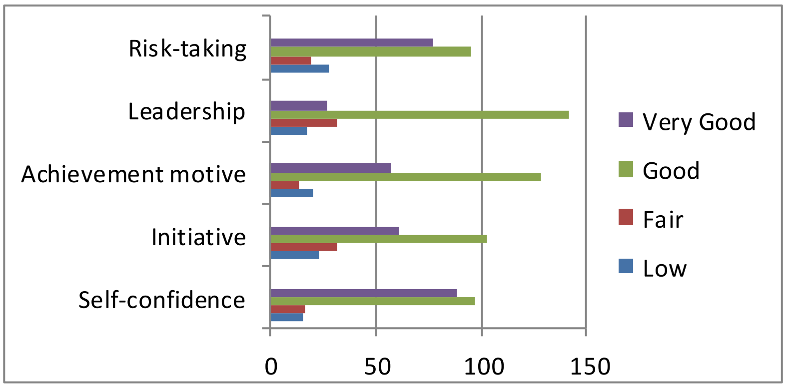

Figure 4. *Students' Entrepreneurial Attitude after STEM-based Science Learning*

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.

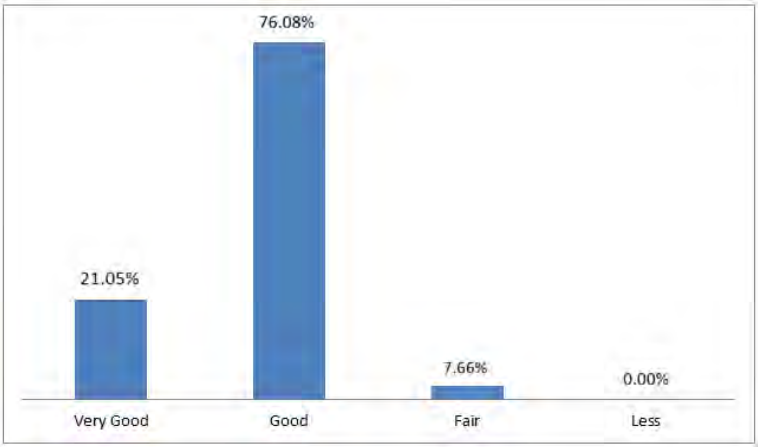

Figure 5. *The Category Percentage of Students' Entrepreneurial Attitudes as the Impact of STEM Approach Application*

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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