STEAM and Environment on students' creative-thinking skills: A meta-analysis study

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Abstract. In the 21st-century, learning based on Science, Technology, Engineering, Art, and Mathematics (STEAM) has been increasingly popular, especially in learning physics at schools. This learning is considered to be able to accommodate many students' abilities, especially in the aspects of understanding and higher-order thinking skills. Through a meta-analysis study, this article discusses how STEAM learning accommodated students' creative-thinking skills. The study was carried out by collecting articles in the Scopus, DOAJ, and ERIC databases. A total of 16 selected articles based on STEAM and creative-thinking skills keywords were analyzed through 5 stages, namely orientation, conceptualization, investigation, discussion, and conclusion. The results of the analysis showed that STEAM learning can improve students' creative-thinking skills. STEAM can be integrated with environment concept. However, research on STEAM and creative-thinking skills has not been done much in the field of physics.

Keywords: Creative-Thinking, Meta-Analysis, STEAM

1. Introduction

Students in the 21st-century are facing real-life problems [1]. These real-life problems cannot be solved easily with traditional education. Traditional education focuses on students' knowledge development but in 21st-century students need skills-based education to deal with real-life problems. Therefore, it is important to determine a method or approach in education [2]. Social and technological changes have been developed in the last few decades and have raised fundamental questions about what kind of skills will be needed by future generations [2,3]. New approaches are needed to improve science learning and make it more interesting [4]. Early education in Science, Technology, Engineering, Arts, and Mathematics (STEAM) has been carried out at STS USA in the 1980s [5]. STEAM is a transition from the Science, Technology, Engineering, and Mathematics (STEM) approach developed in the United States (US) [6]. STEAM is one of the convergence education or advanced concepts of the STEM approach [7].

STEAM is an approach that can be applied in various learning environments, either elementary, junior high, or senior high schools[8]. As technology develops, the STEAM approach is increasingly popular and is used to measure the creative-thinking skills [8-11]; problem-solving [12,13]; concept understanding [14,15]; understanding in the fields of science, technology, techniques, and arts; learning motivation; learning achievement [15]; and critical-thinking. It can make science learning
more interesting [4]. STEAM-based education is more developed worldwide than STEM education. STEAM can be integrated by environmental concept. This environment concept was transdisciplinary with another concept of learning, especially STEAM.

Previous research has also discussed the creative-thinking skills [8,18-20]. Other studies have also discussed the development of early work concepts of STEAM learning with the resulted assumption that humans cannot understand science without technology because the development of science and technology has a major influence on education [18]. Also, art is an important ingredient in interpreting knowledge and technology [19].

This article aimed to discuss the development of STEAM research on students' creative-thinking skills and how to apply them [15]. Research on STEAM has not been widely applied in Indonesia, especially in the field of physics education. This study is focused on reviewing articles about STEAM and its relation to creative-thinking skills considering that this ability is an important skill in the 21st-century and becomes the basis for world progress and development [20]. Besides, creative-thinking skills are also an ability that every individual must have to create new ideas to get a solution to a problem [21]. This article also discussed how students' creativity can be improved by having interesting and relevant activities [22].

2. Method
This study is a meta-analysis study of the result of the previous studies [23] through the quantitative-descriptive method. The sample of this study had been selected by first studying the findings in research articles related to STEAM on students' creative-thinking skills in the context of science learning, especially physics material. The research articles were determined by browsing the Scopus, DOAJ, and ERIC (Education Resources Information Center) databases using the keywords of science, technology, engineering, art, and mathematics (STEAM), STEAM education, creative-thinking, and meta-analysis. Sixteen articles had been selected based on STEAM and creative-thinking skills keywords. Then, the articles were analyzed through 5 stages, namely orientation, conceptualization, investigation, discussion, and conclusion. The stages of this study are displayed in Figure 5.

![Figure 1: Stages of Analysis](image)

The first stage was orientation where the researchers searched for articles related to the topic to be studied in the Scopus, DOAJ, and ERIC (Education Resources Information Center) databases. The second stage was conceptualization where the researcher selected relevant articles on STEAM research and creative-thinking skills. The third stage was the investigation where the researchers investigated and analyzed the articles that will be used as data in the discussion. At this stage, the effect size of the particles obtained was also calculated. The next stage was the discussion. It is the
explanation part of the discussion and the results of the analyzed data. The last stage was the conclusion where the researchers concluded the results of the analysis of the articles.

3. Result and Discussion

The study began by searching popular topics of articles in the last 5 years. Through the orientation stage, the researchers investigated popular keywords from various databases ranging from Google Scholar, DOAJ (Directory of Open Access Journals), ERIC (Education Resources Information Center), Web of Science (WoS), to Scopus. Based on the results of the investigation, the STEAM (science, technology, engineering, art, and mathematics) and creative-thinking skills were selected as the main material for the investigation in the following stage.

The next stage was searching for articles related to STEAM and creative-thinking skills. The data source was limited to 3 indexing databases, namely DOAJ, ERIC, and Scopus based on the ease of access and indexer credibility. Apart from using the two main keywords, other keywords were also searched, namely physics education, science, science learning, and education.

The researchers obtained 151 articles related to STEAM. The data was then analyzed and selected in a more in-depth and specific way to look for articles related to learning, science learning, physics learning, and creative-thinking skills. Based on the results of the investigation, only 16 articles that specifically discussed this matter. The selected article was then subjected to further review processes. The assessment was carried out by investigating the effectiveness of learning science, technology, engineering, art, and mathematics (STEAM) in improving students' creative-thinking skills. The list of the selected articles is displayed in table 1.

| Researchers                  | Country     | Material                        | Level                | Variable                          | Total Respondents | Effect Size (EU) |
|------------------------------|-------------|---------------------------------|----------------------|-----------------------------------|-------------------|------------------|
| Jeong Ah Kim & Heejin Kim    | Korea       | (IT) Programming                | Elementary School   | Creative-thinking skills           | -                 | -                |
| Gulbin Ozkan & Unsal Umdu     | Turkey      | (Force and Energy) Physics       | Junior High School  | Conceptual understanding           | 74                | -                |
| Min Kyeong Kim et al.         | Korean      | Mathematics                     | Elementary School   | Creative-thinking skills           | 273               | 0.73             |
| FAU Anindya IU Wusqo          | Indonesia   | (Light and Optics) Physics       | Junior High School  | Problem Solving and Creative-thinking skills | -                 | 1.99             |
| Catherin Conradty & Franz X. Bogner | Germany | Science                          | Elementary School   | Ability Creative-thinking          | 160               | 0.40             |
| Gita Wandari et al.           | Indonesia   | (Light and Optics) Physics       | Junior High School  | Creative-thinking skills and Concept Understandin g | 27                | 0.75             |
| Songhai & Kyunghee Kang       | Korea       | (Meta-analysis of Physics Trends) Physics | -                   | Creative-thinking skills           | -                 | -                |
Based on the study of the article, the application of STEAM had positive effects on the development of students' creative-thinking skills. In the field of programming, STEAM was able to make students become creative individuals with the addition of art elements in the learning process. It also affected students’ attitudes through the use of educational robots [24]. In mathematics, teachers expressed positive responses on the effectiveness and educational needs of students [2]. In the field of science, STEAM learning was able to improve students’ mastery of concepts based on the results of the gain score \( g \) 0.46 categorized in moderate criteria [14]. In the field of science and art, STEAM learning also affected creative-thinking skills [27-29].

**Table 2. List of STEAM and Creative-thinking skills Studies in Physics**

| Researcher | State | Material | Level | Variable | Total Respondents | Effect Size (UE) |
|------------|-------|----------|-------|----------|-------------------|------------------|
| Gulbin Ozkan & Unsal | Turkey | (Force and Energy) Physics | Junior High School | Conceptual Understanding | 74 | 0.92 |
| FAU | Indonesia | (Light and Junior High) Problem-solving | - | - | 1.99 |

| Jamie Simpson Steele (2016) | Manoa Science Elementary School | Creative-thinking skills | 24 | - |
|---------------------------|-------------------------------|--------------------------|-----|-----|
| Wiliawati et al (2018)    | Indonesia (Water Characteristics) Science Senior High School | Concept understanding | - | 0.46 |
| Siti Wahyuningsih et al. 2020 | Kindergarten Creative-thinking skills | 25 | 0.63 |
| Filiz Gulhan & Fatma Sahin (2018) | Turkey (Reflection in Mirrors and Light Absorption) Science | Creative-thinking skills | 30 | - |
| Olga Shaturnova et al. 2019 | Russian | Creative-thinking skills | - | - |
| Mentari Reza Apriliana et al. (2018) | Indonesia (Acid Bases) Chemistry High School | Creative-thinking skills and Soft skills | - | - |
| Julie Boyle (2019)         | Scotland (Static Electricity) Physics | Creative-thinking skills | - | - |
| Chih-Hung Wu (2018)        | Taiwan Physics | Learning motivation | - | - |
| Kyrie D. Borsay (2018)     | South Lowa (Sound) Physics Elementary School | Creative-thinking skills | 21 | - |
| Researcher          | State       | Material          | Level       | Variable                                      | Total Respondents | Effect Size (UE) |
|---------------------|-------------|-------------------|-------------|-----------------------------------------------|-------------------|------------------|
| Anindya IU Wusqo    | Indonesia   | Physics (Optics)  | School      | and creative-thinking skills                  |                   |                  |
| (2020)              |             |                   |             |                                               |                   |                  |
| Gita Ayu Wandari et al. (2018) | Indonesia | Physics (Light and Optics) | Junior High School | Creative-thinking skills and Concept Understanding | 27                | 0.75             |
| Songhai & Kyunghee Kang (2015) | Korea | Physics (Meta-analysis of Physics Trends) | - | Creative-thinking skills | - | - |
| Julie Boyle (2019) | Scotland    | Physics (Static Electricity) | - | Creative-thinking skills | - | - |
| Chih-Hung Wu (2018) | Taiwan      | Physics | - | Learning Motivation | - | - |
| Kyrie D. Borsay     | Lowa Utara  | Physics (Sound)   | Elementary School | Creative-thinking skills                       | 21                | -                |
| (2016)              |             |                   |             |                                               |                   |                  |

Also in the field of science learning, STEAM affected creative-thinking skills. Catherin Conradty & Franz X. Bogner stated that the addition of art elements using handicrafts can improve students' creative-thinking skills [4]. Jamie Simpson Steele stated that teachers deliberately combined dances to help students learned science concepts while applying the principles of choreography so that they can improvise creative movements to combine wind variations such as zephyr, gusts, whirlwind, and crosswind. They developed the meaning of the content of science while practising the elements of dance [25]. Furthermore, in research conducted by Filiz Guðhan & Fatma Sahin, mirror reflection and light absorption lessons required the right way to attract the attention of students. Thus, the teachers added art in the learning activities by implementing painting and drawing to draw mirrors so that students can be more interested in learning. The students also thought that learning was more fun and not boring. The findings showed that STEAM activities had been evaluated positively and can improve students' creative-thinking skills [26].

Research on acid and alkaline chemicals had been conducted by Mentari Reza Apriliana et al. by applying the STEAM approach using project-based learning to determine the pH of the solution and create natural indicators. This project was carried out by adding art elements which can be seen from the colours produced when testing the acid-base solutions with natural indicators and designing images for aquarium decoration. The results showed that STEAM-based learning can improve soft
skills, creative-thinking, and creative-thinking [28]. Furthermore, based on the research conducted by Siti Wahyuningsih et al. in early childhood study, STEAM learning can encourage children to develop curiosity toward something. STEAM learning also enabled children to improve their creative-thinking skills [29].

Furthermore, STEAM learning affected the conceptual understanding of physics [13]. It affected the creative thinking skills and mastery of concepts [9], affected the problem solving and creative-thinking skills [11], affected the development of creative thinking skills in physics [5], affected the creative-thinking skills [30][31], and learning motivation [32]. Overall, STEAM learning has been able to develop creativity, conceptual understanding, and problem-solving in daily activities [29]. STEAM is the developed version of STEM. The difference between the two lies in the use of art as part of learning. The integration of art in conceptual understanding assisted by drawing activities aimed to encourage students to design and understand conceptual understanding in light and energy lessons while problem-solving and creative-thinking in light and optics lessons, the students were asked to make projects. STEAM encourages the emergence of creative ideas to solve a problem by inserting a figure or colour combination which will increase the value of art in the lesson. The implementation was carried out through drawing, painting, drama, and dancing activities so that the students could broaden their understanding. Through modelling and role-playing, they can easily portray the phenomenon [33].

Further analysis based on the reviewed articles concluded that STEAM research opportunities in the field of physics are still wide open. Out of 16 articles, only seven articles that were focused on the STEAM and creative-thinking skills in physics even though the research on those topics could provide very good impacts [5][8]. These opportunities exist at various levels, including the junior high school, senior high school, and university levels. Besides the creative-thinking skills variable, STEAM-related research also has high opportunities for other variables. STEAM incorporates the idea of trans-disciplinary learning which means students learn through a true blending of the disciplines and that they are solving problems set in a real context [35]. In trans-disciplinary teaching, students become so occupied in problem-solving with their prior knowledge and learn new concepts from the different STEAM disciplines to reach a solution [36]. Teachers’ purpose of science teaching learning was to make students attentive in the class by creating an enjoyable classroom environment. Using teaching aids in science classes is very essential because it helps students to learn more easily and effectively [37]. Problem-solving skill is the most important ability for students to understand the knowledge and prepare them to survive future real-life challenges especially in STEAM education [38]. So, STEAM learning needs to incorporate in the curriculum to prepare students appropriately for the unpredictable future.

Environmental concepts can also be taught using the STEAM approach. This is because environmental science is a transdisciplinary science and is integrated with various other concepts. A lot of research can be done by linking various environmental concepts and other concept related to science, Technology, and engineering [39-44]. This allows the environmental learning to be integrated with STEAM. The concept related to air and water pollution is an environmental issue related to STEAM. Apart from that, it is also related to sustainable development programs that also need to be further developed. STEAM supports the efforts of the community and students in making sustainable development programs run well. To support this, it is necessary to make an effort to support sustainable development with environmental education innovations. One of the environmental education innovations that can be developed is with teaching materials and environmental learning media [45-52].

4. Conclusion

Based on the results of the study, STEAM learning is appropriate to improve students' creative-thinking skills. However, in physics learning, research on STEAM has been rarely done. There are only seven articles that discuss STEAM in physics learning. This indicates that research on STEAM learning in physics has been rarely done, especially in improving creative-thinking skills. The STEAM
learning on creative-thinking skills is quite an effectiveness to be applied to other subjects. Therefore, the opportunity to research STEAM learning in physics is wide open, especially in improving students' creative-thinking skills.

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