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Students' Perspectives about Science Technology Engineering Art and Math in Application to Physics Measurement Equipment Projects

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Abstract: This research aims to describe student perspectives about STEAM in application to Measurement Physics Measuring Instrument Projects. Research focuses on 23 students enrolled in the Physics Education Study Program at the Palangka Raya State Islamic Institute. The research used descriptive qualitative-quantitative and utilize a Likert scale to conduct a survey. Five projects implemented in this research are DC voltmeter project, galvanometer project, project to determine spring constants, vernier caliper project made from bamboo, sensory equipment project to detect water levels. The integration of STEAM with each project is a holistic methodology that commences with empathetic identification of a problem, followed by ideation through testing, and culminating in the acquisition of knowledge from prototypes and literature to inspire further innovation. According to the results, the five projects described for the science component ($\bar{x} = 4.47$; $SD = 0.07$), technology component ($\bar{x} = 4.22$; $SD = 0.30$), engineering component ($\bar{x} = 4.19$; $SD = 0.01$), art component ($\bar{x} = 4.03$; $SD = 0.31$), and mathematics component ($\bar{x} = 4.48$; $SD = 0.15$). In conclusion, five projects strongly approved as constructive project with STEAM application.

Keywords: Perspectives; PjB; STEAM.

Introduction

The application of STEAM learning at various levels of education is an idea that has been launched to answer the challenges of the world of work in the 21st century. Various references have confirmed that current and future jobs require understanding and skills in the STEAM field starting from understanding medical diagnosis, evaluating developments in lifestyle and environment, to managing daily activities with various computer-based applications (Ozkan & Topsakal, 2020; Peppler & Wohlwend, 2018). In the arts field, for example, jobs such as making musical instruments also need to apply STEAM in order to produce musical instruments as expected. Musical instrument makers need to master science in order to produce rhythmic musical instruments; need to master the technology of how to make musical instruments; need to master the technique of arranging scales; need to master the art of musical beauty to be able to produce the correct scale; and need to master mathematics to be able to calculate the material price of a musical instrument (Belbase et al., 2022).

The advantages that emerge from the application of STEAM in learning activities provide opportunities for various educational fields to integrate it into learning activities, more specifically physics learning. Applying STEAM in physics learning will help teachers increase the growth of students' mindsets in learning. The combination of physics learning with STEAM can build new research skills that are capable of developing cognitive and physics knowledge construction. STEAM implicitly includes the teaching of art and design, and also provides space for skills closely related to cross-disciplinary creativity and innovation. STEAM-based learning activities in physics learning provide

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opportunities for analytical thinking and application, but are not only limited to problem solving, concrete thinking, language and speech processing, logic, mathematical calculations, and memory retrieval (Hogan & Down, 2016). These activities must also provide opportunities for creative thinking and application including visual literacy, artistic processes, storytelling, abstract thinking, spatial awareness, interpretation of context, and meaning and experimentation in the application of design elements and principles (Liao, 2016; Supriyadi et al., 2023).

Physics learning by integrating STEAM can be exemplified by making a prototype of a flute musical instrument. This learning will develop students' critical thinking, creative thinking, communicative and collaborative abilities. Creative thinking abilities emerge when students are directed to focus on understanding the interconnection between the concepts of resonance, organ pipes and strings in sound waves in solving problems. When designing and testing prototypes of flute musical instruments with the help of various sound applications, creative thinking abilities will be further developed. Critical thinking skills will emerge when students are asked to design procedures and organize musical instruments, then convey creative ideas both in terms of concept and practice in making procedures and designs for musical instruments from used materials. Communication skills will emerge when students convey ideas, in discussions about resonance in organ pipes and strings, trial and error, looking for solutions to each problem and presenting the results of instrument design trials. Student collaboration in this learning can be observed from cooperation in groups when discussing the concept of sound waves assisted by applications. This description provides information that the increase in students' various abilities in learning physics can be accommodated by integrating STEAM.

The processes and products described above are the main nature or essence of physics learning. This nature clearly has dimensions that can be pursued with STEAM for realization. This section places a strong emphasis on integrating STEAM in physics learning. Physics products which tend to be abstract in nature are packaged in the form of physical and logical-mathematical knowledge which not only contains theories or formulas to be remembered, but also contains concepts which must be understood in depth, which is a serious challenge for teachers in teaching physics in the classroom. On the other hand, the availability of facilities in physics learning is limited and how teachers present ideal physics learning always has an impact and consequence on the limited supporting facilities and infrastructure. By integrating STEAM, teachers can overcome various limitations in facilities and infrastructure with the help of various technologies. The use of STEAM as an alternative to overcome the availability of facilities and infrastructure in physics learning is a new breakthrough to improve the quality of physics learning. Therefore, this research tries to reveal students' perspectives about STEAM in its application to physics measuring equipment projects. Where, in the physics learning curriculum, measuring instruments are the initial part that students must understand well.

Method

Learning in higher education to explicate perspective (Roux et al., 2019), here were five measurement equipment projects created by the participant in this study (N=23). The students come from the physics education study program in IAIN Palangka Raya who completing the sixth semester by making a project related to physics learning. The researchers are lecturers in Physics Study Program with different courses. Data consisted of journals in literature review and survey. The method used the qualitative-quantitative descriptive method (Vaismoradi, Turunen, & Bondas, 2013) as shown in Figure 1. The participant created projects in group collaboration and fulfilled surveys after finished the measurement equipment projects.

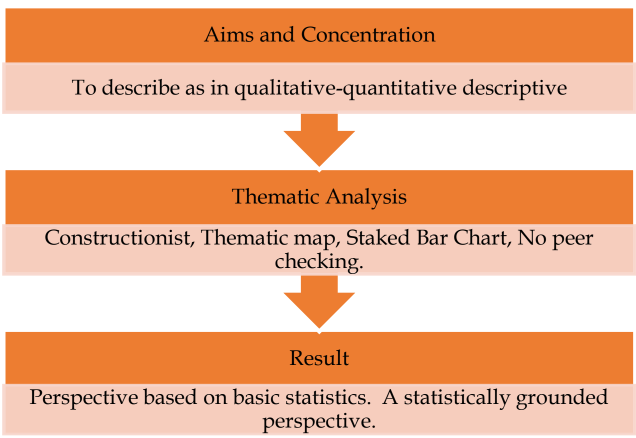

Figure 1. Adaptive diagram illustrating the essential of qualitative methodology

The poll used a 5-Likert scale as a study instrument (Averin et al., 2017) as in Table 1. Mean for central tendency, standard deviation for variance, Pearson's r for associations, and t-test for others are used in thematic analysis of 5-Likert scale data. The selection of this analytical technique was based on its specific characteristics, as outlined (Wu, 2007), including the significance of the output value, critical evaluation, and underlying philosophy. These factors were carefully considered in order to ensure the most appropriate and effective approach was utilized. By taking into account the nuances of the method, we were able to make an informed decision that would yield the most accurate and reliable results. This demonstrates our commitment to utilizing best practices and ensuring the highest level of quality in our analytical processes.

Table 1. Score Interpretation in Instrument

Options in 5 Likert Scale	Score
Strongly Disagree	1
Disagree	2
Neutral	3
Agree	4
Strongly Agree	5

Result and Discussion

Learning theory, according to the constructionist viewpoint, includes two types of constructivism (Liu, 2010). The first is cognitive constructivism, which Jean Piaget pioneered. This theory deals with scheme understanding, assimilation, accommodation, and equilibration. It holds that people build their own understanding of the world by their experiences and interactions with their surroundings. Cognitive constructivism places significant emphasis on the active engagement of learners in the process of learning and the development of cognitive structures that enable them to effectively organize and comprehend incoming information.

Moreover, it is imperative to adhere to the principles of active learning, which necessitates a comprehensive, authentic, and genuine approach to achieve optimal results. The social constructivist viewpoint will examine the relationship between language and thought, with a focus on The Thematic Map represented in Figure 2.

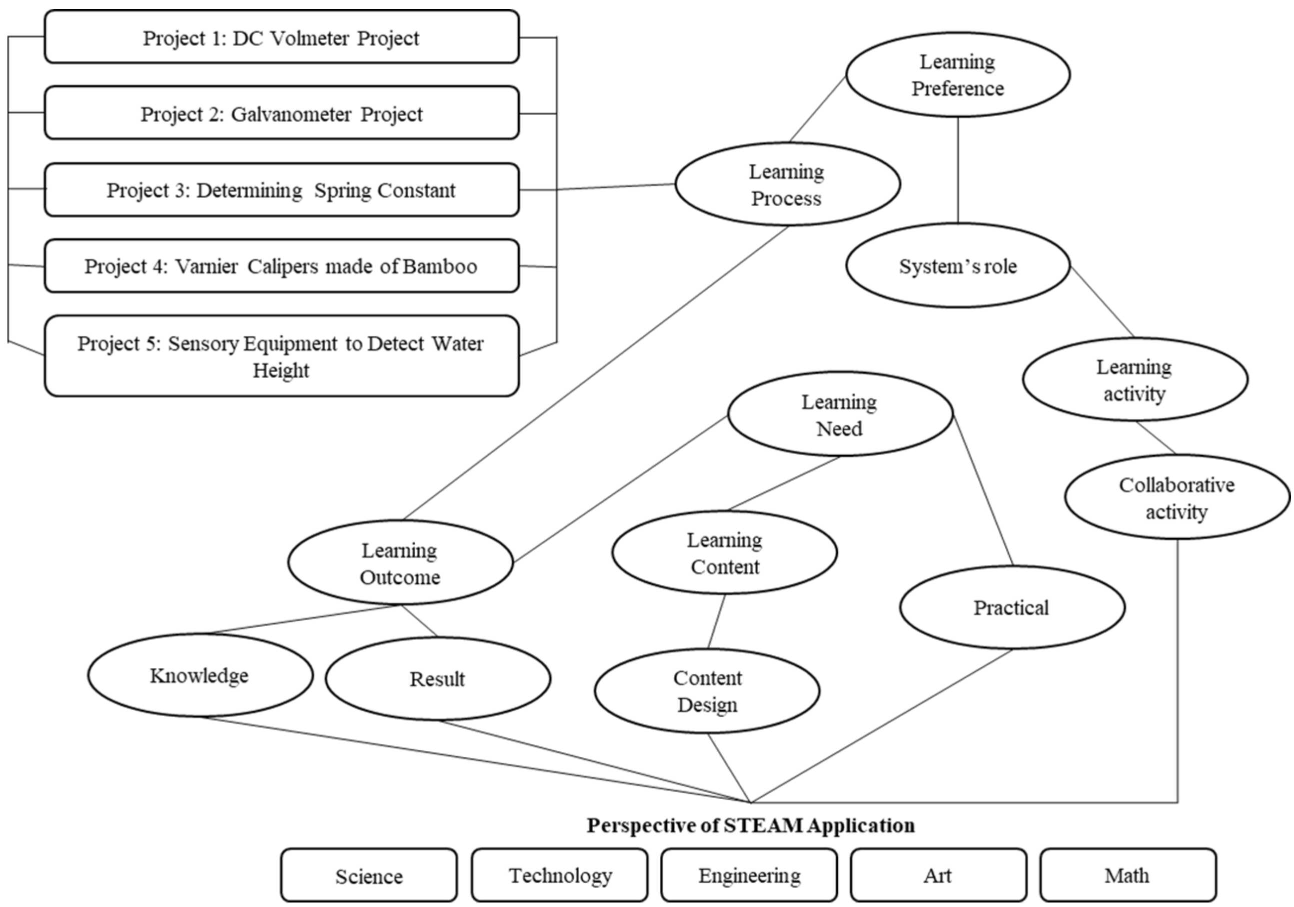

Figure 2. The thematic map for constructivism in analyzing the perspective of STEAM application to 5 measurement equipment projects

Perspectives on applying STEAM differed throughout the five topics of the physics measuring tool project. Fundamentally, physics and project outcomes were highlighted as learning objectives. Projects with subjects created by students in the Physics Education study program were outlined as learning content based on learning needs and indirectly enable students to make tools based on learning needs. There were bound to be financial limits with project-based learning activities, which is also a factor frequently indicated by the lack of practicum/measuring instruments in physics learning, therefore cooperative learning as an ideal solution.

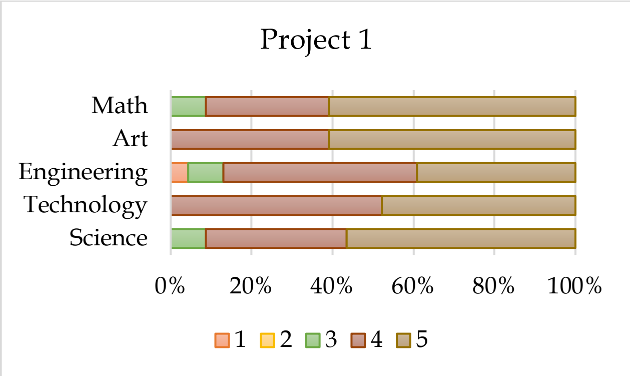

Figure 3. The percentage of STEAM in DC voltmeter project

The collaborative learning implemented through project improved student's critical thinking (Ratnasari & Hendayana, 2020). The comprehension of this scientific concept facilitates the development of a DC Voltmeter and the interpretation of readings derived from analog indicators. When the DC Voltmeter project failed, the students in the group kept trying to finish it and ensure that the DC Voltmeter operated. The failure to motivate intellectual endeavor persisted. (Huxster et al., 2017). The viewpoints of students regarding the fundamental nature of engineering in the DC Voltmeter Project were categorized as strongly agreeing, agreeing, neutral, and strongly disagreeing. Over the strongly agree response regarding the essence of engineering that has been applied to the DC voltmeter project, one of the students said that the DC voltmeter is a project with a built schematic, structured design.

When project 1 was created, the results of the analysis were in line with learning with an anababe thinking framework (Kholifudin, 2014) where an analog screen was created by adjusting the factory product to the tool that had been made. The measurement results are compared indirectly. C6's cognitive competence in making project 1 was the re-creation of an analog DC voltmeter with the application of Ohm's Law and Faraday's Law. Study of DC Electricity material will further support students in understanding the functions of differentiated electrical properties. The measuring instrument in project 1 will be widely used in measuring voltage in direct current machines such as DC motors and DC generators (Firmansyah et al., 2017) but with different maximum voltage capacities.

The Galvanometer Project collected student viewpoints on the fundamental nature of science, with responses indicating high agreement, agreement, and neutrality. A prominent reaction that strongly agreed with the project's scientific essence was that it consisted of a succession of interdependent actions that combined both scientific and technological techniques. The response shown that the Galvanometer project as learning content to reached the objective of this study by practical though varied in the patterns of attainment (Shogren et al., 2014). As well as The activity of building a DC Voltmeter, Galvanometer project was founded on the basic idea of studying the presence of an electric current in an electric circuit. The Galvanometer was built with two types of electric current in mind: direct current and alternating current. With a fixed tension but varied resistance settings, the analysis up to project construction can lead to basic physics expertise.

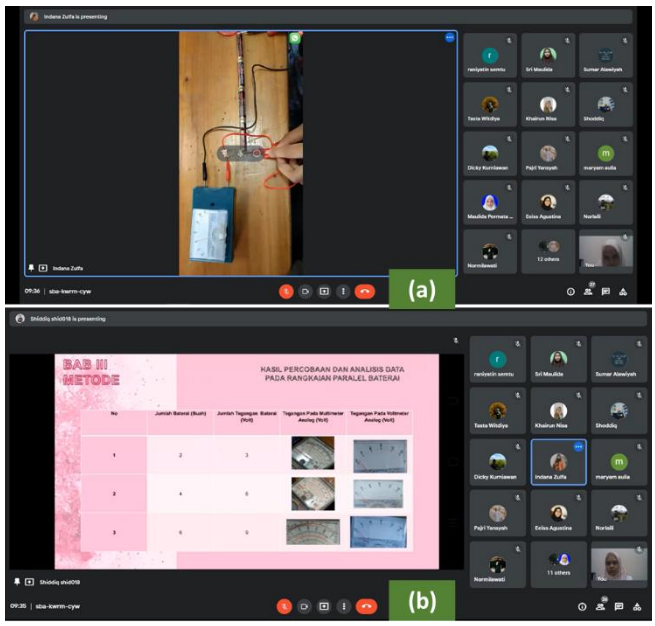

Figure 4. (a) The tool made by the group with project 1 is presented in class online; (b) There is a process of comparing measurements using a DC Voltmeter that has been finished by the factory with the DC Voltmeter produced by Project 1.

The response expressed that the student understood fundamental principles, even though the Galvanometer had no innovation potential(Go & Hart, 2016; Tiwana & Mclean, 2005). According to replies, the application of STEAM essences challenges educators to create computational thinking in physics measuring equipment projects, as described in the Conde article. (Conde et al., 2019). Student perspectives on the essence of math was applied in Galvanometer Project provided responses as strongly agree, agree, and neutral. One of the Neutral responds was, Galvanometer related to accuracy so it could measure current in electricity.

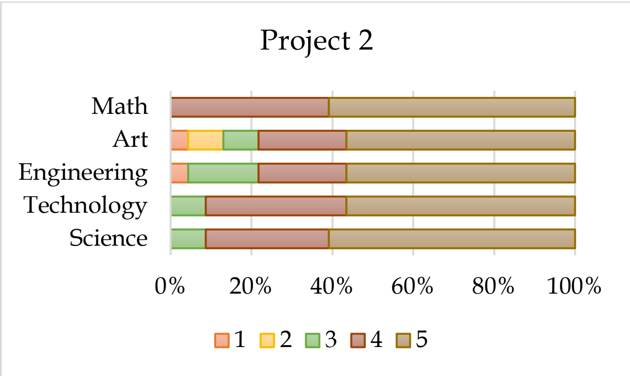

Figure 5. The percentage of STEAM in galvanometer project

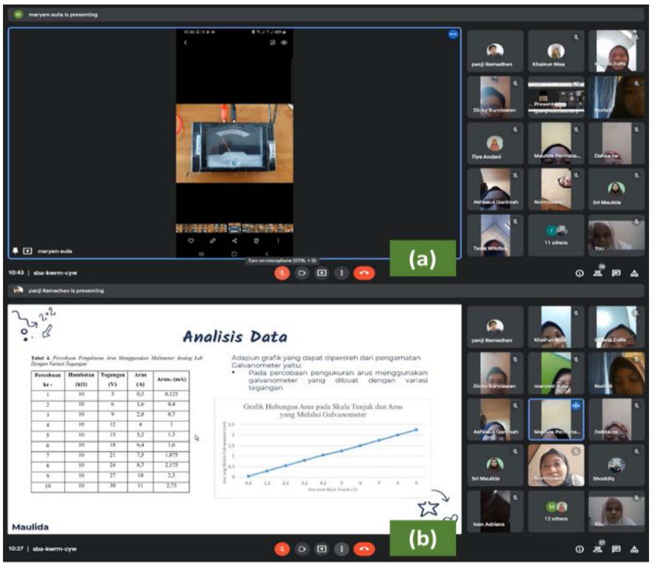

Figure 6. (a) The tool made by the group with project 2 is presented in class online, (b) There is a measurement process using a Galvanometer that was made in project 2.

Similar to the DC Voltmeter in project 1, the Galvanometer is a practical tool that supports understanding electrical concepts. However, the application of Faraday's Law which is read on an analog screen (Permadi et al., 2018) is not explained as measuring magnetism into electricity. In project 2 data analysis there are only electrical measurements such as voltage and electric current which are unidirectional. Although currently there has been a lot of development in Interactive Multimedia (MMI) to understand the subject of magnetic electricity (Fatima et al., 2014), project 2 is a breakthrough for students in being scientific. Apart from that, there has been a lot of research that shows that teaching aids are an effective solution in increasing understanding of dynamic electrical concepts (Hasbi et al., 2015).

The Average estimation of strongly agree responses to Technology, Engineering and Art application said that to make spring needed technology to engine so it could be an art spring. Similar to generic research that cited spring as a physics and engineering application (Serna & Joshi, 2011). According to the study by Serna and Joshi, the crew that created Project 3 had problems digesting three different types of springs with varying degrees of flexibility. The significance of the difference in the flexibility of this spring will aid students in carrying out the analysis by allowing them to differentiate the spring constant depending on their vertical view.

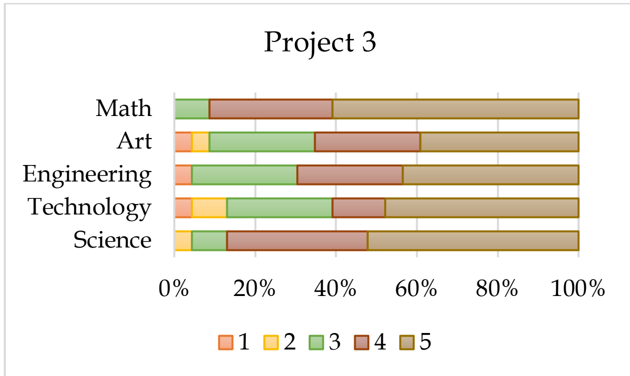

Figure 7. The percentage of STEAM in determining spring constant

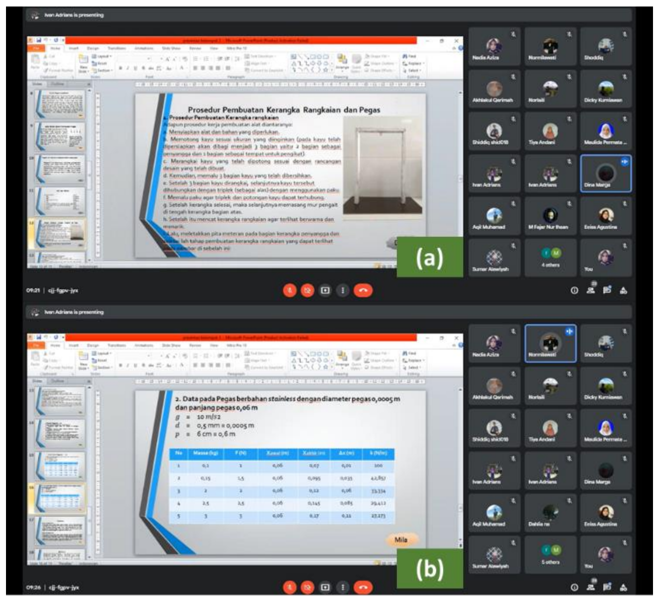

Figure 8. (a) The spring frame made by the group with project 3 is presented in class online, (b) There is a measurement process using the tools that have been made in project 3.

Mastery of the concept of simple harmonic motion becomes more meaningful when learning is carried out experimentally (Armiati et al., 2020). Learning that is directly connected to daily life means that the information obtained during the learning process is stored in long-term memory. The existence of simple harmonic motion props in measuring the elastic properties of a spring provides an overview of the quality of learning for its effectiveness (Buhungo et al., 2023). The contextual nature of learning will be better supported by modules that can improve students' creative thinking abilities (Bili et al., 2022). Project 3 is a comparison between real laboratory learning and virtual laboratory-based learning when network-based learning requires students to keep their distance (Zulkifli et al., 2022) for material on elasticity and Hooke's law. In fact, virtual laboratory-based learning is accompanied by discovery learning models in achieving understanding of simple harmonic motion (Tupalessy et al., 2022). Project 3 which shows the existence of multiple representations in studying the subject of elasticity and Hooke's law. If the tools in project 3 are used in learning, they can increase student motivation (Doyan et al., 2018).

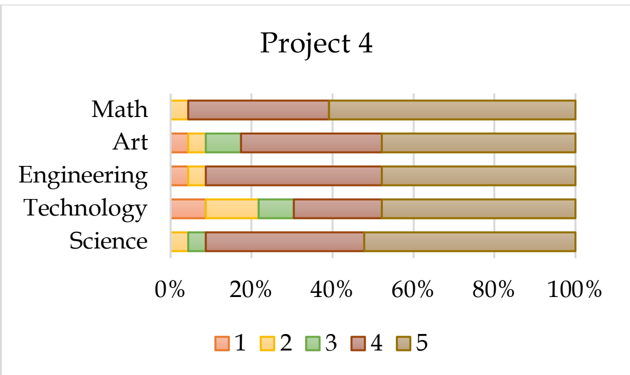

Figure 9. The percentage of STEAM for the project of vernier calipers which was made of bamboo.

Student perspectives on the essence of math in the Vernier Calipers made of Bamboo project responded strongly agree, agree, neutral and disagree. The Average of strongly Agree responses of the application of math in the Vernier Calipers made of Bamboo project said that t make sure the vernier caliper in accuracy needed math to get right gear with correct black gap so it could be moved to measure an object. While the disagree, response said that in the vernier caliper making did not need math. Yang (2020) claims that the production stayed within the technological design tolerances. Students' abilities are developed indirectly by their participation in teamwork, which allows them to understand the mechanics of the tool.

Vernier calipers are one of the iconic demonstration media in mastering length measurements. As for iconic display media, there is also an idea that shows that learning allows attention and concentration (Ropi`i., 2019). As an innovation in studying length measurement, an iconic display media that is not facilitated in schools, Project 4 is the solution. Based on natural materials around, iconic display media such as vernier calipers can be used in learning. The condition of the school facilities is such that project 4 can be used as community service. This service can be carried out as training in the use of calipers for MA students (Mufarrih et al., 2022). As an innovation, calipers made from bamboo must meet the specifications of physics laboratory equipment (Fidiantara et al., 2021). However, project 4 has not yet entered tool testing. However, the tool was developed by comparing measurement results using project 4 results with measurement results using factory-made calipers. Not only physics subjects will benefit if the lack of caliper facilities is overcome with tool-based tools such as project 3 but also other science disciplines. An example of the use of a caliper not only as a physical measuring tool can be seen in chemical research (Dewi et al., 2019).

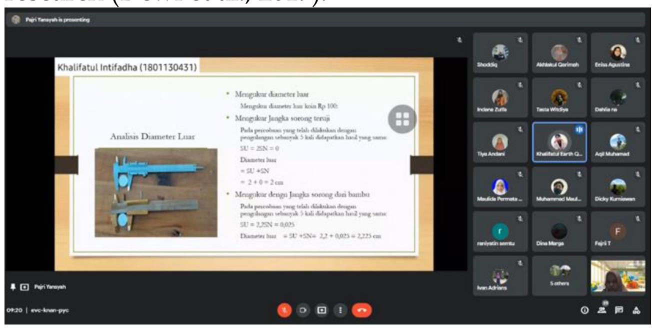

Figure 10. There is a process of comparing measurements using a Vernier Caliper that has been made by the factory with a Vernier Caliper from Bamboo as a result of Project 4 and is presented in class online

Notably, a respondent expressed strong agreement with the assertion that the determination of the distance between each LED required mathematical processes. This underscores the critical role of mathematics in the successful execution of the project. The findings suggest that a sound understanding of mathematical principles is essential for the development of effective sensory equipment for water height detection. Further research is needed to explore the specific mathematical concepts and techniques that are relevant to this application.

The background of project 5 is a school located on the banks of the Kahayan River in Palangka Raya which can flood at any time when the rainy season arrives. Inspired by making a prototype for monitoring dam water (Setiawan et al., 2018), project 5 is intended as a demonstration tool in physics learning. However, with limited tools, project team 5 carried out literacy, so that project 5 was closely related to the relationship between voltage and resistance in electricity. The science process skills demonstrated by project team 5 in this research are in accordance with learning with a STEAM approach which provides direct experience related to real conditions in the natural surroundings (Sakdiah et al., 2022). Even though there was no pre-test or post-test in the assessment in Project 5, the relationship between real conditions, electrical physics material, and the existence of demonstration facilities makes this project-based learning constructive and conventional.

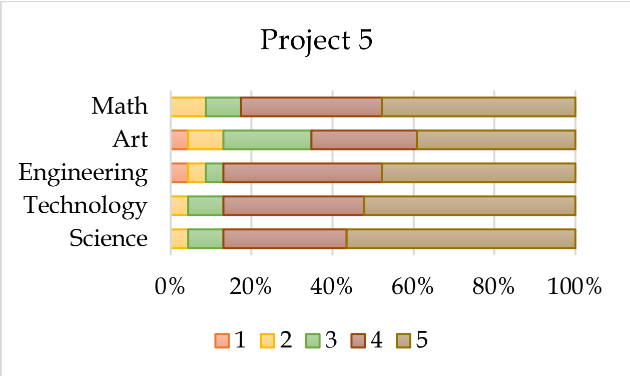

Figure 11. The percentage of STEAM for the project of sensory equipment to detect water height.

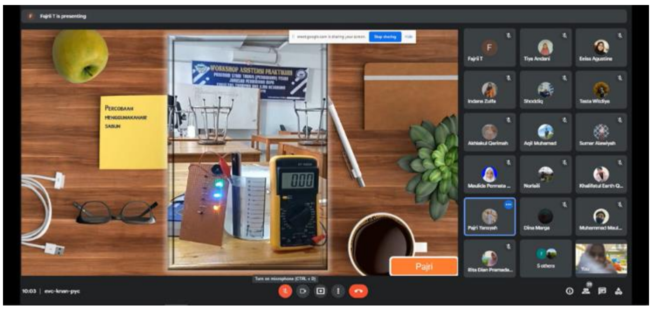

Figure 12. Simulation of a water level detection demonstration tool resulting from Project 5 and online presented.

Figures 13 and 14 show the aggregate outcomes of five measurement equipment projects, each seen through the lens of STEAM application from the perspective of project students. The average ratio of STEAM perspectives on projects is in accordance with the development of students' abilities in communicating and skills in collaborating in project-based learning with a STEAM approach (Dharin et al., 2023). Although there is no influence between learning models and science process skills (Dewi et al., 2017), lectures with project-based product output require students as prospective teachers to think creatively and adaptively in providing facilities for learning.

There is a correlation in project-based STEAM that does not show a relationship between scientific attitudes in completing each project. In fact, if we review the mastery of concepts before the physics measurement tool was created, we can test critical thinking skills. The opposite of this condition is shown more in guided inquiry-based physics learning which requires student reference in achieving the goals to be achieved in learning (Sudarmini et al., 2015).

Thuneberg et al. (2018) suggest that the integration of art into inquiry-based learning can be facilitated through the use of mathematical modules. Additionally, the STEAM approach to education highlights three distinct functions of art: esthetic learning, contextual comprehension, and creativity. The aforementioned statement appears to be at odds with the current implementation of STEAM in art classes, as it has been reported to yield positive results The STEAM approach was effectively implemented by the educator in the art class, as described in an article. The inclusion of art as a component has significantly enhanced the STEM approach. The incorporation of art has sparked heightened enthusiasm for STEM education, affording students the opportunity to grasp mathematical principles through the prism of aesthetics and the natural world.

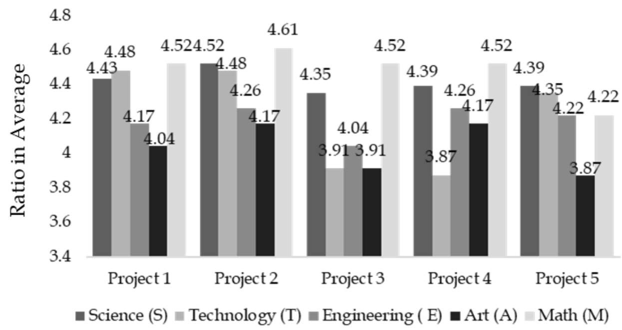

Figure 13. The ratio in average of STEAM components of the 5 projects.

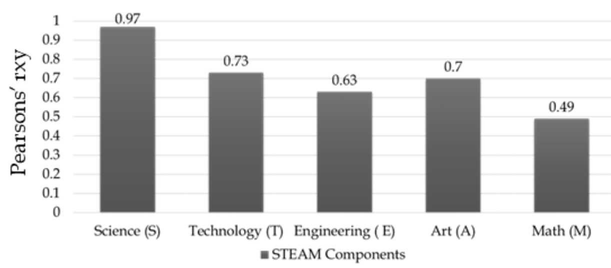

Figure 14. The correlation ratio for each component in STEAM in making the 5 projects.

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While some individuals hold this belief, others are cautiously scrutinizing the role of art within the STEAM framework (Ozkan & Topsakal, 2020; Peppler & Wohlwend, 2018). The substantial association between art and STEM education shows that the latter can be significantly improved by art. (Hogan & Down, 2016). The correlation between the application of art and the five projects is significantly positive, as evidenced by a coefficient of r = 0.70. While some individuals hold this belief, others are currently engaged in a comprehensive analysis of the role of art within the STEAM paradigm. The high association between art and STEM education suggests that the latter can be greatly improved by incorporating art.

The integration of STEAM with each project is a holistic methodology that commences with empathetic identification of a problem, followed by ideation through testing, and culminating in the acquisition of knowledge from prototypes and literature to inspire further innovation (Graham & Graham, 2021). Through the project-making process, students are exposed to a range of skills that are essential for success in STEAM fields. This approach is designed to provide students with a holistic understanding of STEAM and its applications, while also fostering their creativity and problem-solving abilities.

Making projects in physics learning seeks to solve complex problems that involve creativity in a systematic manner. (Sasmita & Hartoyo, 2020). The correlation significance, which was only 0.62 in the medium category, failed to demonstrate the close association between project-based learning and the engineering component. Based on the process used to develop a project, aspects of perceptions about the level of student illustration in visualizing concepts need to be researched in greater depth. The current phase, akin to the testing and repair stages, commences with the identification of issues and limitations by each group. Five unique project subjects will reveal diverse methodologies.

STEAM context consists of projects, priorities, procedures, and issues. (Belbase et al., 2022). From the discovery of the frame problem through the description of the show, there is no investigative process. Although the act of continuously refining an issue until it can be refined further may indicate creativity within the transdisciplinary inquiry paradigm (Costantino, 2018), the emphasis continues to be on procedures and methods. The spotlight is on the structured and organized approach to problem-solving and decision-making. The concentration is on the established protocols and guidelines that guide actions and behaviors. The stress is on the disciplined and rigorous approach to achieving results. The concentration is on the consistent and repeatable processes that lead to success. The focus remains on the processes that drive performance and deliver outcomes.

The integration of STEAM can also foster creativity and innovation, preparing students for future careers in the field. The inclusion of STEAM Application in electricity education can provide a comprehensive education that equips students with the necessary skills and knowledge to succeed in the industry. Because of the constructivist approach to learning, the possibility of a project being technology-related remains conceivable, despite its absence of link with electricity. The implementation of this approach facilitates the involvement and self-management of tertiary level students (Banihashem et al., 2021), while also enabling the integration of technology into their projects. The study reveals a noteworthy positive correlation between the utilization of technology and the five projects, with a coefficient of 0.73.

According to the average responses, the five measurement equipment projects got strongly agree responses by the mean (4.42) by the science application. The discussion includes achieving an all-encompassing and empirical perspective. The relationship between conceptual knowledge and scientific explication begins with the act of observation and concept formation (Milner-Bolotin et al., 2021; Nasir et al., 2022). Making an effort together, the fact was that not everyone attempted the same thing, and the advantages for the team can be extremely distinct. (Maros et al., 2021). Students' empathy and perspective-taking are critical components of STEAM projects.

An A for STEAM acronyms has thee topic areas (Esthetic Learning, Contextual Understanding, Creativity) (Liu et al., 2021). Figure 9 shows a significant association between scientific application and the five projects, as indicated by a Pearson's r value of 0.971. The integration of science, technology, engineering, arts, and mathematics (STEAM) is accomplished by providing opportunities for hands-on skill development using physics measuring equipment. This method effectively bridges the gap between theoretical concepts and practical application, allowing students to develop a more in-depth comprehension of scientific principles. Individuals are equipped with the skills and information required to excel in a quickly expanding technology landscape by utilizing STEAM education. (Ozkan & Topsakal, 2020). The interconnection between the comprehension of STEM and its perspectives is a complex matter, encompassing various aspects such as pedagogical strategies and participant involvement (Jackson & Mohr-Schroeder, 2018). Despite the limited understanding of STEAM, the challenges of STEM education remain prevalent within the curriculum.

It is imperative that educators and policymakers alike prioritize the implementation of STEAM education in order to address these challenges and provide students with a well-rounded education that prepares them for the demands of the modern workforce. By embracing STEAM, we can equip students with the skills and knowledge necessary to succeed in the 21st century. (Herro & Quigley, 2017). To ensure the effectiveness of STEAM education, it is essential to create an environment that fosters creativity, critical thinking, and problem-solving skills. Ultimately, the success of STEAM education depends on the commitment and collaboration of all parties involved. The students employ a variety of approaches to tackle intricate problems while concurrently augmenting their comprehension of the subject matter.

Prioritizing interactive learning has been found to improve students' ability to remember material and apply it in real-world settings, resulting in better academic and professional outcomes. This method stresses active participation and engagement, which allows students to develop critical thinking and problem-solving skills. Students are encouraged to apply their knowledge in a collaborative and dynamic setting by adding interactive aspects such as group discussions, case studies, and simulations. As a result, individuals are better equipped to face complicated obstacles and achieve success in their chosen industries. Prioritizing interactive learning is thus an effective method for boosting student achievement.

Conclusion

The present study reports on the constructive outcomes of the five physics measurement equipment projects when applied in the STEAM context. The discussion includes an analysis of qualitative-quantitative data, such as responses, mean, standard deviation, Pearson's validity test (r), and association t-test. However, the T-test is not elaborated upon in this study. The findings validate the effectiveness of the initiatives in the STEAM domain, underscoring their capacity to augment academic achievements in the realm of physics instruction. These findings have significant implications for educators seeking to integrate STEAM approaches into their teaching practices. STEAM principles will have a significant impact on the cognitive processes of students participating in cooperative and project-based physics learning. The project itself, which may take the shape of a text-based product, acts as a vital link between the STEAM approach and physics instruction. STEAM components will be coordinated at various stages during the product's manufacture. The creation of evaluation indicators for STEAM (Science, Technology, Engineering, Arts, and Mathematics) in the context of physics education represents a promising area for future expansion.

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Author Contributions
Nadia Azizah was responsible for ideation, design development, translation, process management, data analysis, results, and final editing. Hadma Yuliani was tasked with composing literature reviews, while Mardaya was responsible for organizing discussions and conclusions. Jhelang Annovasho oversaw the research and ensures the conclusion is well-organized.

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No conflict of interest is declared by authors.

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