ENHANCING STUDENTS' MATHEMATICAL THINKING THROUGH THE QURAN - SCIENCE, TECHNOLOGY, ENGINEERING, ARTS, AND MATHEMATICS (Q-STEAM) MODULE

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Abstract: Students' mathematical reasoning abilities are relatively low. To enhance these skills, specific teaching and learning strategies can be implemented, which require students to engage in problem-solving activities and apply their knowledge to real-life situations. This research adopts a quantitative approach to examine the Q-STEAM module's effects on students' mathematical thinking skills. The participants of this study consisted of 65 senior high school students from Aceh, who were selected using convenience sampling and divided into experimental and control groups. The study employed a quasi-experimental method with a pretest-posttest non-equivalent group design. The research employed an essay question as a tool for mathematical thinking instruments. The data collected from the mathematical thinking test was analyzed using an independent sample t-test. The findings revealed statistically significant differences in the mean scores of mathematical thinking skills between the two groups. Furthermore, the descriptive statistics showed that the students in the experiment group had better mathematical thinking skills than those in the control class.

Keywords: Q-STEAM Module, Mathematical Thinking, Mathematics Learning

INTRODUCTION

It is well known that the classroom's mathematics teaching and learning process still disregards the development of students' mathematical thinking skills (Gravemeijer et al., 2016). Several studies that have been conducted in Indonesia indicate that high school students and undergraduates have a low level of mathematical thinking. (Delima et al., 2019; Marjuwita et al., 2020; Sari & Nurfauziah, 2019; Siagian & Sagala, 2021). International research has consistently found that students' mathematical thinking remains underdeveloped (Jawad, Majeed, & ALRikabi, 2021; Kooloos et al., 2021; Singh et al., 2018). This data is also fully supported by the executive summary of the 2019 national exam results published by the Indonesian Ministry of Education, which states that most students cannot solve non-routine problems to acquire high-level thinking skills (Kemdikbud, 2019). The benchmark for higher-order thinking is equivalent to the mathematical literacy question employed by the Programme for International Student Assessment (PISA). According to the PISA 2023 findings, Indonesian students' mathematical literacy ranked 68th out of 81 countries participating in PISA (OECD, 2023). According to Stacey (2006), mathematical literacy, as assessed by PISA, is a component of mathematical thinking ability.

Mathematical thinking is one of the most essential terms in mathematics education.Thus, it becomes the highest goal in learning mathematics at school (Drijvers et al., 2019; Goos & Kaya, 2020). According to NCTM (2020), mathematical thinking is defined as the ability to explore, construct conjecturesand reason logically, solve unconventional problems, convey ideas about mathematics and use mathematics as a communication tool, connect ideas within and between mathematics, and engage in other intellectual activities in mathematics.

The development of students' mathematical thinking skills is contingent upon creating a classroom environment in which mathematics teaching reflects the ways of thinking used by mathematicians (Breen & O'Shea, 2021). Mason et al. (2010) mentioned that there are four basic processes in the formation of students' mathematical thinking ability: 1) specialization, the ability of students to try several problems by looking at examples, 2) generalization, the ability of students to discover patterns and relationships, 3) the ability of students to predict relationships and 4) convincing, the student's ability to find and present reasons why something is true.

Students can achieve the development of mathematical thinking skills by implementing effective learning strategies, such as asking thought-provoking questions, presenting complex problems, encouraging critical thinking, and implementing project-based learning (Delima et al., 2019; Marjuwita et al., 2020; Stacey, 2006). A practical method to improve students' thinking skills is by implementing student-centered teaching methods during classroom teaching (Demo et al., 2021; Rich, 2021). The STEAM approach is one of such student-centered approach. It can be defined as a learning approach that integrates the subjects of science, technology, engineering, arts, and mathematics in a single session.

Yakman, the early founder of STEAM, proposed a framework to add art (A) to STEM education. The STEAM approach, as defined by Yakman (2008), encompasses five levels: 1) lifelong learning, 2) integrated learning, 3) multi-disciplinary learning, 4) subject learning, and 5) content-specific learning. To meet the needs of students in relation to the importance of religious knowledge that has become synonymous with local wisdom, the teaching of mathematics must integrate the Al-Quran. This integration can be written as Quran - Science, Technology, Engineering, Arts, and Mathematics (Q-STEAM). Teaching with Q-STEAM is a project-based approach that develops students` mathematical skills while focusing on their religious understanding and social skills that they will use in everyday life. STEAM integration with Al-Quran understanding in learning mathematics at school is presented as an educational module on differentiating algebraic functions. The construction of teaching and learning modules will increase student survival (Novalia & Noer, 2019; Rasul et al., 2017), critical thinking skills (Linda et al., 2019; Syafari, 2020), and understanding (Lin & Chang, 2019).

The Q-STEAM module's implementation in the teaching and learning process will help students understand and discover mathematical topics through the projects they create. Each project written in the module will begin with religious concerns that typically occur among students. Then, students will be required to solve the problem by integrating the principles of Islamic religious education, science, technology, engineering, art, and mathematics in an integrative manner. Finally, assisting students as mathematicians in getting and answering mathematical problems can ultimately enhance students' mathematical thinking abilities. This module not only teaches mathematical principles, but students will continue to be exposed to the concepts of Islamic education related to the theme of differentiation so that it will bring them closer and continually remind them of Allah SWT.

Using the STEAM idea along with understanding the Al-Quran is done in an integrative way. This method was chosen because school project learning aligns more with the themes and subjects listed in the curriculum than just based on current projects and well-known scientific ideas. Integrating the Al-Quran into teaching and learning will be included in the core stage of completing the prepared project. This research focuses on designing the Q-STEAM module using the Engineering Design Process (EDP) model developed by the Massachusetts Department of Education. The integration model for Al-Quran into STEAM learning is adapted from the framework proposed by Abdussakir and Rosimanidar (2017) and subsequently applied to the components of STEAM learning. The outline of the model for merging Al-Quran and STEAM components includes mathematics and science 1) derived from Al-Quran; 2) for Al-Quran; 3) to explore Al-Quran; 4) to explain Al-Quran; 5) to deliver Al-Quran; and 6) with the Al-Quran.

METHODOLOGY

The application of the Q-STEAM module to teaching mathematics was carried out using a quasi-experimental approach. This approach was chosen to ensure that the research implementation naturally occurs without randomly assigning students to specific groups. Instead, students were placed in groups based on their existing class (Piaw, 2011), thereby avoiding any perception of being treated as experimental subjects. This approach is expected to enhance the validity of the research findings.It also account for certain external factors beyond the researcher's control during the study. The research design employed in this study is a pretest-posttest, non-equivalent group design. The Q-STEAM module was tested on a research sample consisting of 63 grade XI students at one of the schools in Pidie district specializing in science. In addition, the selection of classes to be utilized as experiments and control groups will be conducted using convenience sampling.

The instrument used to measure students' mathematical thinking is a set of mathematical questions in the differentiation topic. These questions are formulated based on the competencies outlined in the school curriculum and the learning aspects that have been emphasized. The selected questions are sourced from final exams and university entrance exams and have been adapted from the work of Aydin dan Ubuz (2014). The questions designed to measure students' mathematical thinking skills consist of four essays. The constructed mathematical thinking instrument achieved a moderate difficulty level, a strong discrimination index, and

Cronbach's alpha coefficient value exceeding 0.7. This finding demonstrates that the mathematical thinking items in the differentiation title have a high level of reliability, which is statistically significant.

The findings of this study were analyzed through an independent sample t-test to assess the differences in mathematical thinking mean scores between the experimental and control groups. The pre-test results were also utilized to gauge the initial mathematical thinking proficiency before the study.

RESULTS AND DISCUSSION

Pre-Test Results

This section examines the pre-test findings to determine the mean difference between the two groups for the mathematical thinking variable. The findings of this study indicate that the mathematical thinking between the two groups differed, with the experimental group having a mean of 37.62 and the control group having a mean of 35.61. An independent sample t-test was then undertaken to ensure substantial differences between the means for the control and treatment groups. These data reveal that the average of students' mathematical thinking in the issue of differentiation has a variance uniformity, and the data are normally distributed for the experimental and control groups. Subsequently, an independent sample t-test could be performed for the pre-mathematical thinking test results, with the outcomes presented in Table 1.

Table 1
The result of the independent sample t-test for the pre-mathematical thinking test

		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Mathematical thinking	Equal variances are assumed.	.366	61	.716	2.011	.366
	Equal variances are not assumed.	.366	60.995	.716	2.011	.366

Table 1 shows that the probability of significance (α) is more significant than 0.05 (α = 0.716). This finding shows that the average level of mathematical thinking in the control and treatment groups is the same. The results of the analysis of the pre-mathematical thinking test show no significant difference between the means of the two groups. However, the mean for both groups on the variable of mathematical thinking is different.

Post-Test result

An independent sample t-test was conducted to examine the effectiveness of the Q-STEAM module on students' mathematical thinking. The initial normality test and data uniformity stage were conducted for the post-test findings. Shapiro-Wilk test analysis showed that the data were normally distributed for the mathematical thinking test for the control and experiment groups. Furthermore, Lavene's test confirmed that the data distribution was uniform across both groups. The detailed results of the independent t-test for the mathematical thinking post-test data can be found in Table 2.

Table 2
The result of the independent sample t-test for the pos–mathematical thinking test

		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Mathematical thinking	Equal variances are assumed.	6.06	61	.001	25.265	4.163
	Equal variances are not assumed.	6.04	55.746	.001	25.265	4.182

The data presented in Table 2 indicate that the probability value is less than 0.05, equal to 0.001. The statistical test results indicate the rejection of the null hypothesis, which states that there is no significant variance in the mean of mathematical thinking between the control group and the experimental group following the implementation of the Q-STEAM module. The findings highlight a significant difference in mean mathematical thinking between the experimental and control groups. Furthermore, descriptive tests were conducted to determine the group with a higher mean. Data analysis revealed that the control group had a mean of 45.51 with a standard deviation of 18.7011, whereas the experimental group had a mean of 70.78 with a standard deviation of 14.09. The analysis of the study's findings has addressed the research question regarding the difference in mathematical thinking between the group utilizing the Q-STEAM module and the group using textbooks. The results demonstrate a substantial difference in students' mathematical thinking mean between the control and experimental groups, with those using the Q-STEAM module displaying a higher mean in mathematical thinking than those using textbooks.

The Q-STEAM module is designed according to project-based learning; students will be presented with contextual problems often encountered daily. With an integrated approach and project-based activities, students are empowered to tackle mathematical problems with the same level of proficiency as professional mathematicians. Moreover, the Q-STEAM module has provided several activities that arouse students' curiosity and involve current technology use. Next, students will use all their knowledge, information, and skills in an integrated manner to find a solution to the given problem. Students can select a suitable design based on their information and experience. The Q-STEAM module allows each group to discuss and brainstorm ideas based on its members' collective information and knowledge. Effective communication skills within the group play a significant role in successfully achieving the assigned project. Every group member must possess communicative and persuasive abilities to guarantee that the material supplied is accurate and well-received by other members. In addition to persuasive skills, students must also display generalization and specialization skills to present solid arguments for each proposed notion.

The Q-STEAM module has been designed according to systematic Engineering Design Process (EDP) steps so that students will get used to 1) specializing in each given problem, 2) generalize about the problems found, 3) conjecturing possible solutions that can be used in the solution problem, and 4) convincing others of the solution they have given. More specifically, the relationship formed between mathematical thinking and learning using EDP is shown in the following table.

Table 3
The relationship of EDP with mathematical thinking

The EDP Steps	Levels of mathematical thinking	Students' activities
- Ask: Identify the Needs and Constraints. - Research the problem.	- Specializing	- Students analyze the issues presented in the module, establishing links between the given problems and their knowledge and comprehension. Furthermore, during this phase, students explore multiple sources to gather relevant information for problem-solving.
- Imagine: Develop Possible Solutions.	- Generalizing	- Students look for a pattern to solve the given problem, referring to the information obtained from the previous stage.
- Plan: Select a Promising Solution.	- Conjecturing	- During this phase, students are working on creating a solution to address the problem provided. At this stage, the student has formulated a solution that has the potential to resolve the given problem effectively.
- Create: Build a prototype. - Test and evaluate the prototype. - Improve: Redesign as needed.	- Convincing	- At this stage, students will try to convince others that the provided solution is accurate and suitable for resolving the given problem. They will commence by initiating the development process, testing the solution, and subsequently engaging in a forum to communicate the steps they have taken. If any inconsistencies persist, proceeding with the rebuilding process is recommended.

The findings of this study demonstrate that integrating the Q-STEAM module in mathematics instruction has enhanced students' mathematical thinking abilities and made students act as mathematicians who discover mathematical concepts. These findings align with prior studies exploring the correlation between the STEM approach, project-based learning, and students' mathematical thinking development. The study of STEM bears a significant resemblance to that of STEAM, as the latter is built upon an understanding of the former (Yakman & Lee, 2012). Notably, there is a lack of research specifically examining the impact of the Q-STEAM on mathematical thinking. While research on integrated learning approaches and cognitive development exists, investigations into the impact of the STEAM approach on mathematical thinking are limited. Previous studies by Gunadi et al. (2023), Jawad et al. (2021), and Miller (2019) have examined the correlation between integrated learning strategies and cognitive processes.

The Q-STEAM module's teaching is what makes project-based learning the main activity in solving mathematical problems. The findings of this study are consistent with the study conducted by Kartini et al. (2019). Furthermore, the findings indicate that mathematical thinking is more than solving arithmetic or algebraic problems. It is a holistic way to look at something, disaggregate it into important numerical, structural, or logical things, and then analyze the basic patterns which forms mathematics. Mathematical thinking is the mental activity experienced by students when faced with a problem that must be solved. According to Mason et al. (2010), everyone has the potential to develop mathematical thinking, which is a significant objective in mathematics teaching in schools.

The main barrier to teachers' ability to develop students' mathematical thinking is that teachers generally do not get adequate support from the school. No support is especially received in terms of learning materials, references, and professional development training. As a result, many teachers still lack the knowledge and resources to integrate mathematical thinking activities into mathematics instruction. Consequently, they lack the essential knowledge and resources required for this purpose. Furthermore, in addition to grappling with a lack of clarity, teachers face the daunting task of dedicating extra time and effort to acquire necessary supplies. This challenge is further compounded by the cultural orientation towards exams and the heavy workload imposed on teachers.

Despite teachers' various problems and challenges, every teacher firmly believes in the significance of fostering mathematical thinking during mathematics lessons. Lim and Hwa (2006) propose several recommendations to enhance students' mathematical thinking in the classroom. First, it entails improving and completing mathematics teachers' comprehension of mathematical thinking. Secondly, it entails implementing collaborative lesson studies to deliver mathematical thinking lessons. Lastly, it necessitates redesigning an assessment framework that emphasizes mathematical thinking.

This research has had a significant impact on the field of mathematics education. Its primary achievement is creating a module for algebraic functions that teachers and students can utilize. This module is designed based on project-based learning with the Q-STEAM approach. The study's contribution is expected to inspire educators to adopt this module as a reference for developing similar modules in various subjects. Another noteworthy contribution of this research is the development of a module that enhances students' mathematical thinking, an aspect often overlooked in traditional school teaching. The study aimed to align national educational objectives with contemporary demands and student needs. As a result, this module will serve as a valuable resource for teachers in their mathematics instruction and as a guide for imparting religious knowledge to students.

Based on the findings of this research, several suggestions can be proposed for further investigation. The initial recommendation is to conduct a study to develop a module focusing on various topics and lessons rather than solely concentrating on one specific area. It would allow for a more comprehensive understanding of the subject matter. Furthermore, it is suggested that a Q-STEAM module be designed and developed with an emphasis on the variables of mathematical thinking. Subsequently, future studies could expand upon this by examining the impact of the Q-STEAM module on other variables that are believed to be interconnected with the developed concept. It would provide a more holistic view of the module's effectiveness. Finally, it is advised that further studies focus on developing an electronic module that can easily integrate with an electronic platform. It would provide students with a convenient way of designing solutions for projects. Moreover, through aligning with current educational trends and technological advancements in the students' world, an electronic module would enhance the learning experience and facilitate students' engagement with the material.

CONCLUSION

The main goal of this study is to assess the effectiveness of the Q-STEAM module in improving high school students' mathematical thinking abilities on algebraic function derivatives. The results of this study demonstrate

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a significant disparity in the mean mathematical thinking scores between students who use the Q-STEAM module and those who rely on traditional textbooks. Notably, students who engage with the Q-STEAM module exhibit a higher mean score. The Q-STEAM module has proven instrumental in improving students' mathematical thinking skills because it familiarizes them with systematic and programmed problem-solving techniques. Furthermore, the Q-STEAM module has enabled students to recognize the practical applications of learning algebraic function derivatives in religious contexts.

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