Journal of Education and Learning (EduLearn)
Vol. 18, No. 2, May 2024, pp. 462~470
ISSN: 2089-9823 DOI: 10.11591/edulearn.v18i2.21080

Science learning STEM-R approach: A study of students' reflective and critical thinking

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Article Info

Article history:

Received Jul 1, 2023
Revised Oct 9, 2023
Accepted Oct 23, 2023

Keywords:

Critical thinking
Islamic school
Reflective thinking
Science learning
STEM-R

ABSTRACT

This study aimed to i) analyse learning problems in science at boarding schools for junior high school students and ii) determine the effectiveness of science learning in the context of Islamic teachings using the science, technology, engineering, and mathematics, -religion (STEM-R) approach to improve reflective and critical thinking skills. The research method applied in this study was a sequential exploratory mixed method. The research design consisted of five stages: i) qualitative data gathering, ii) qualitative data analysis, iii) quantitative data gathering, iv) quantitative data analysis, and v) data interpretation. The subjects of this study were 192 students from boarding schools and were divided into 6 groups. The research results obtained were the school, parents, science teachers and religion teachers' vision and mission causing students to like or dislike science. An excellent teacher is viewed by students as someone who can make learning enjoyable, exhibit creativity in presenting educational material, possess the ability to motivate, link science and religion, engage in investigative activities, infuse humour, establish connections between science and everyday life, and communicate concepts effectively. Moreover, distinctions in reflective thinking and critical thinking abilities were observed between the experimental group and the control group. Learning that connects science and Islamic religion and examines STEM-R aspects is able to develop students' thinking skills.

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1. INTRODUCTION

Science is a knowledge having an essential role in the 21st century, most actions undertaken by humans are closely tied to the utilisation and implementation of scientific principles. Emphasizing critical thinking skills is a fundamental objective in science education for addressing the challenges of daily life in the twenty-first century, as highlighted in scholarly research [1], [2], as well as being of particular concern to higher education institutions and the workforce [3], so that it can improve a person's quality in analysing and assessing a problem [4], and increase logic to produce solutions and arguments in solving problems [5]. Based on the results of Organization for Economic Co-operation and Development (OECD) research on the

2018 PISA ranking, Indonesia was positioned at the 71st rank among 79 countries in the field of science, as reported in reference [6]. This shows that students' critical thinking skills in Indonesia are still very low and need to be developed since elementary education. Based on some of these research results, studies are needed to develop critical thinking skills. The results of a preliminary study of critical thinking skills on tahfidz boarding school students in Central Java province with 120 students obtained an average of 64.8 included in the low category. These results are in line with previous research by [7].

Indonesia, where 87% of the population, totaling 209.12 million people, follows Islam, holds the position of having the world's largest Muslim population. Consequently, Islamic cultural values wield significant influence in the realm of education [8]. The proliferation of tahfidz boarding schools has surged rapidly in terms of quantity; however, there is a noticeable gap in achieving the desired quality. This quality, encompassing the creation of graduates who are devout believers, proficient in science and technology, has not been adequately realized. It's acknowledged that the quality of the learning environment significantly impacts the successful attainment of the intended learning objectives [9].

Historically, a perception emerged during the 13th century that propagated the separation of science from religion, resulting in a stigma that the two were unrelated in the realm of education. This notion of educational epistemology advocated for secularism and a disconnect between science and religion [10], [11]. To counter this perception and bridge the gap between science and religion, one effective strategy is the integration of the two. Integrating Islamic science into the educational landscape involves infusing Islamic values into the teaching of science and related subjects, creating a holistic knowledge foundation for students [12].

In this study, the integration of Islamic science involves incorporating Islamic values, particularly through the utilization of "selawat" in science education. This modification aligns well with the characteristics and backgrounds of students in Islamic boarding schools, as mentioned in references [13], [14]. By integrating science with Islamic principles, a comprehensive understanding is achieved, enhancing student performance in both scientific and religious studies [15], [16]. This integration not only adds meaning to the learning experience [17] but also facilitates effective learning [18]. It's crucial to highlight that integrating Islamic values into science education using the science, technology, engineering, and mathematics (STEM) approach is a novel aspect of this research. Consequently, this study aims to delve into the challenges of science education within boarding schools, particularly emphasizing Islamic values, and to evaluate the impact of incorporating Islamic teachings in science education using the STEM approach.

2. LITERATURE REVIEW

Incorporating Islamic science education with scientific greetings should be integrated with a contemporary learning approach focusing on XXI century skills, such as the STEM approach. STEM is an educational framework that seamlessly integrates these four key disciplines—Science, Technology, Engineering, and Mathematics—creating an interconnected and comprehensive learning experience [19]. The outcomes of research indicate that employing a project-based STEM approach substantially amplifies students' grasp of the significance and applicability of science [20]. improves cognitive abilities [21], engineering skills of junior high school students [22], critical thinking [23], and make learning effective [24]. Project-based learning is very appropriate for use in interdisciplinary learning [25], has a positive effect on scientific writing and communicating research results. Research on the STEM approach and Islamic science is still being studied separately, not yet integrating the two. The problems that exist in the tahfidz boarding school, a solution will be proposed, namely designing and implementing Islamic science learning using the science, technology, engineering, mathematics and religion (STEM-R) approach. This learning is thought to be able to foster interest in studying science and being able to develop critical thinking skills.

The goal of STEM education is to apply basic knowledge from STEM to problems that students encounter in everyday life, to become STEM literacy [19]. STEM is an interdisciplinary approach due to authentic teaching of two or more STEM subjects related to practice so as to increase students' interest in learning [26] Design learning activities that are oriented to the problems of everyday life, with a learning process based on finding solutions to existing problems is a feature of STEM learning. Cultural and environmental differences between countries make STEM experience modification and development aspects of approaches to learning. The STEM approach in South Korea gets additional art because South Korean society is synonymous with the world of art, so the Korean Ministry of Education (MOE) added the "Art" aspect in STEM to STEAM namely science, technology, engineering, art, and mathematics [27]. Indonesia, being predominantly Muslim, is deeply influenced by Islamic culture, significantly shaping its educational framework, particularly within Islamic boarding schools. This influence has sparked the notion of integrating religious aspects (Religion) into the STEM approach, giving rise to STEM-R. The results of [28] state that in the Qur'an there are more than 750 verses about the universe (Science). Whereas in the

Kauniyah verse, it is hoped that students can be found in science learning with an integrated STEM-R approach to Islamic science to understand science deeper.

According to research findings, integrating Islamic values into science learning involves three key strategies: i) associating Islamic values with each subject through Islamization, such as initiating learning with Islamic greetings and prayers, ii) commencing every activity with reciting basmalah, and iii) exploring Qur'anic verses and Hadith to establish scientific evidence for the value of science [29]. For instance, a teacher might elucidate Qur'anic verses and Hadith concerning environmental pollution hazards, prompting students to contemplate and engage in scientific work related to environmental pollution ranging from composing essays on pollution prevention efforts to devising tools for pollution control. In this study, the integration of Islamic science aims to blend the integration of religion with science utilizing Qur'anic verses or Hadith (STEM-R approach) and incorporate the established learning model at tahfidz Boarding Schools, specifically integrating selawat with science.

In the majority of Islamic boarding schools, the learning process typically commences with reciting selawat and incorporates the use of nadzom or songs with lyrics containing essential keywords related to the material being studied. Selawat constitutes a form of praise directed towards Prophet Muhammad and is viewed as a form of worship that brings individuals closer to Allah [30]. Meanwhile, nadzom serves three primary functions within Islamic boarding school learning: entertainment, educational and instructional, and spiritual [31]. Firstly, nadzom functions as a source of entertainment due to its literary value and is commonly sung, accompanied by musical instruments or without. Secondly, it operates in an educational and instructional capacity as its content embodies educational values and scientific concepts. Lastly, nadzom holds a spiritual function, serving as educational materials or learning media for students [32].

In this study, the proposed selawat science song is intended to enhance students' enjoyment and enthusiasm in learning science by incorporating essential keywords related to the science material. Unlike traditional memorization, students will read this song at the beginning of their learning sessions. When individuals engage their senses simultaneously - eyes, ears, and mind - new expectations, attitudes, and habits are formed as a result of cognitive processes [33].

STEM serves as both an approach and an endeavor to amalgamate four knowledge domains based on real-life problem relationships [28]. By authentically teaching two or more STEM subjects related to practical applications, the STEM approach aims to heighten students' interest in learning and practical activities, thereby motivating their engagement with science [26], [34]. Integrating the STEM-R approach into science education within Islamic boarding schools is crucial, particularly at the junior high school level. This integration involves infusing Islamic values into the science curriculum, creating a comprehensive knowledge framework within students [12]. This research endeavors to blend Islamic science learning with the STEM-R approach, utilizing the science selawat to enhance the critical thinking skills of tahfidz boarding school students.

The instructional framework for learning Islamic science with the STEM-R approach comprises seven phases, beginning with the introduction phase. In this preliminary phase, the teacher initiates discussion about previously studied environmental pollution material, encouraging students to reflect on God's creation and its connection to environmental pollution. Students collectively recite the selawat science song focused on environmental pollution (Islamic science).

The teacher then outlines the learning objectives and forms student groups. Phase two involves determining the fundamental question, wherein the teacher presents a problem stimulus related to environmental pollution for students to observe and analyze through reading activities, observations, or visual aids. Students, in groups, observe and analyze problems in the textbook linked to environmental pollution, paying attention to STEM-R aspects. Phase three focus on designing the project plan. Students discuss their project observations and document their findings. They answer questions based on the observations, provided in the textbook, and identify additional questions related to the material or pictures.

The teacher facilitates this phase by encouraging students to generate and address a variety of questions during the learning activities. Continuing to Phase 4, students, within their groups, diligently and critically collect a variety of information from various reputable sources, including books and the internet. This responsible gathering of information is essential to support their responses to the posed questions. The teacher guides and encourages students to conduct experiments, seek explanations, and propose solutions to environmental pollution issues, all while considering the STEM-R aspects. Students correlate experimental data with information from diverse sources, synthesize their findings, and prepare for their subsequent work. In Phase 5, known as Testing Results, each group presents their findings through a structured presentation, which is then followed by direct responses and feedback from other groups. Students are tasked with processing and analyzing the data and information collected from various sources, enabling them to address the formulated questions comprehensively. Phase 6 involves Evaluating the Experience, where students analyze and assess the answers obtained for the existing problems. This phase incorporates brainstorming

sessions where both teachers and students collaborate to draw conclusions regarding essential points derived from the environmental pollution learning activities. Additionally, students reflect on and document important insights gleaned from the learning activities. Building on the findings from previous studies, it is anticipated that employing the STEM-R approach in science learning can significantly enhance the critical and reflective thinking skills of tahfidz boarding school students.

3. RESEARCH METHOD

This research employed a mixed-method approach, encompassing both quantitative and qualitative methods. The applied research design followed a sequential exploratory design, commencing with a qualitative study to formulate the research problem. The outcomes of the qualitative study were then utilized to structure research questions for further investigation through quantitative studies [35]. The research design involved five stages:

- Qualitative data collection to identify issues related to science teaching in classrooms;
- Analysis of qualitative data gathered in the first stage to formulate research questions;
- Quantitative data collection through an experimental study employing a non-equivalent control group design and measuring research variables;
- Quantitative data analysis using measures and independent t-tests;
- Interpretation of data and conclusion drawing based on the results from both qualitative and quantitative studies.

The sample for this research comprised 192 students from three Islamic boarding schools, selected using purposive sampling. Data from the qualitative study were collected by identifying, drawing, and interpreting data related to problems in science teaching. On the other hand, quantitative data were collected and analyzed using the Independent T test to determine inter-group differences [36].

4. RESULT AND DISCUSSION

4.1. Problems of learning science in boarding schools

Students' choice of Tahfidz boarding school is influenced by various factors such as the attitudes of science and religion teachers, the school's vision and mission, as well as parental attitudes. Among these factors, the role of the science teacher stands out significantly in influencing students' preferences for attending Hafidz boarding schools. Students emphasize the importance of learning science as it serves as a foundational knowledge for advancing to higher levels of education, pertains to daily life, holds relevance to Islamic teachings, and is inspired by Islamic figures who contributed to the understanding of natural science. However, it's noteworthy that a majority of student responses suggest a perceived disconnect between science and religion. This underscores the need for schools to rethink and align their approach, packaging science and religion learning in line with the vision and mission of religious educational institutions. In this context, science teachers play a vital role and should possess the ability to seamlessly integrate science and Islam within the realm of education. This integration implies infusing Islamic values into the teaching of science and related subjects, thereby fostering a comprehensive knowledge base within students [12]. It's crucial for schools to address this perception gap and work towards integrating science and religion effectively, providing a holistic and meaningful learning experience for students.

From the perspective of students, an effective teacher embodies qualities such as making learning enjoyable (fun learning), employing creative teaching methods, instilling motivation, establishing connections between science and religion, engaging in investigative activities, incorporating humor, and effectively relating science to everyday life. However, a significant hindrance to effective science education stems from the readiness and competence of the teacher [37]. In Indonesia, this is exacerbated by science teachers who often lack competence, struggling to demonstrate the science process effectively within the classroom [37]. Additionally, some teachers face challenges in implementing diverse approaches, utilizing various media and learning resources, as well as facilitating interactive and student-engaging learning experiences [38]. An essential factor in successful science learning is the teacher's understanding of the subject matter and pedagogic content. Unfortunately, competency tests have revealed that a considerable number of science teachers in Indonesia do not meet the required standards, scoring poorly in competency assessments [39]. Merely transmitting knowledge without fostering critical thinking and deeper understanding may result in students who can merely recite scientific facts, lacking a deeper comprehension of the subject [40]. The pivotal role of the teacher involves creating an enriching and enjoyable learning environment that challenges students and makes learning a rewarding experience [41]. Addressing these challenges and enhancing teacher competencies is vital for fostering effective science education.

4.2. The effectiveness of science learning in the text of Islamic teaching using the STEM-R approach

Effectiveness is seen from the achievement of students' reflective thinking and critical thinking and the difference with the control group. The results of data analysis are presented in the Table 1. Decision making on the results of testing the hypothesis using the one sample t test, namely H_0 is denied and H_a is approved if the t-count value < t-table or based on the significance value. If the significance value is > 0.05, it can be concluded that the hypothesis Ha is accepted. Based on the significance value/T count presented in the Table 1, it can be concluded that there are differences in critical thinking and reflective thinking for the experimental class. This means that all classes have a score of > 76 or it can be said that it has proven effective in achieving the minimum completeness set in this study. The results of data analysis are presented in the Table 2.

Table 1. One sampel T test

Variable	Test group	T count	Significance	df	Note
Critical thinking	E1	4.562	0.00	31	There're differences
	E2	4.421	0.00	31	There're differences
	E3	3.364	0.02	31	There're differences
Reflective thinking	E1	4.383	0.00	31	There're differences
	E2	4.201	0.00	31	There're differences
	E3	5.397	0.00	31	There're differences

Note; E: experimental class

Table 2. Normality test data for critical and reflective thinking

Variable	Data group	Significance score	Note
Critical thinking	1	0.19	Data normal
	2	0.29	Data normal
	3	0.13	Data normal
	4	0.06	Data normal
	5	0.53	Data normal
	6	0.34	Data normal
Reflective thinking	1	0.08	Data normal
	2	0.45	Data normal
	3	0.34	Data normal
	4	0.13	Data normal
	5	0.74	Data normal
	6	0.20	Data normal

Based on the Table 2, the decision to conclude is normal or not based on the significance value. If the significance value is > 0.05 then all data is normal. Significance value> 0.05, it is concluded that the data is homogeneous and can be continued for hypothesis testing. The results of homogeneity test are presented in the Table 3.

Table 3. Homogeneity test for critical and reflective thinking

Variable	Levene statistic	df1	df2	Sig.	Note
Critical thinking	0.45	5	186	0.823	Data homogen
Reflective thinking	0.91	5	186	0.48	Data homogen

Based on the Table 3, the decision to conclude the data is homogeneous/not based on significance value. If the significance value is > 0.05 then all data is homogeneous. The significance value of the three variables is > 0.05, so it is concluded that the data is homogeneous and can be continued for hypothesis testing. The results of independent t test are presented in the Table 4.

Decision making from the independent t test hypothesis test, namely if the t-count value > t-table, then H_0 is rejected and Ha is accepted. If the t-count value is < t-table, then H_0 is accepted and Ha is rejected. Based on the calculated t value presented in from the table 4, it can be concluded that there are differences in critical thinking and reflective thinking for the experimental and control classes.

Decision making on the results of testing the hypothesis using the one sample t test, namely H_0 is rejected and Ha is accepted if the t-count value < t-table or based on the significance value. If the significance value is > 0.05, it can be concluded that the hypothesis Ha is accepted. Based on the significance value/T count presented in the Table 4, it can be concluded that there are differences in critical thinking, reflective

thinking, and social skills for the experimental class. This means that all classes have a score of > 76 or it can be said that it has proven effective in achieving the minimum completeness set in this study.

Table 4. Independent T test

Variable	Test group	T count	df	Note
Critical thinking	E1, K1	6.763	62	There're differences
	E2, K2	8.488	66	There're differences
	E3, K3	6.789	62	There're differences
Reflective thinking	E1, K1	6.964	66	There're differences
	E2, K2	6.316	62	There're differences
	E3, K3	7.700	66	There're differences

Note: E: experiment class, K: control class

The results of the data analysis concluded that learning science in the Islamic context with the STEM-R approach was effective in increasing reflective thinking and critical thinking. Students take part in science lessons that are linked to the values of Islamic teachings and are studied from the STEM-R aspect. On the topic of the environment, students discover that the environment on earth was created for humans and must be maintained. Human-caused damage to the environment. Environmental learning presents problems for students to solve after examining aspects of science, technology, engineering, and mathematics and religion then to find solutions. Learning activities carried out by students train the ability to think reflectively and think critically. Someone who has developed higher-order thinking skills is characterized through scientific activities such as: i) conveying ideas that have never been proposed by others; ii) finding new applications to clarify existing knowledge or understanding; iii) connecting existing ideas to formulate new ideas; and iv) proficient and imaginative in solving both structured and unstructured problems [42]. Students are said to have high-order thinking skills if they carry out the following activities: i) deeply recognize basic knowledge and learn something new, ii) open new ideas, and iii) look for material sources to develop existing ideas [43]–[45] states that learning science based on scientific methods and process skills can improve students' level of thinking, academic success, and their attitude towards scientific knowledge. The research states that teaching is to put students through processing information, creating, discovering, exploring and imagining, presenting, applying and transforming scientific knowledge [46]. Reflective thinking skills will be formed through the process of students responding to problems in learning whose solutions cannot be solved directly, so educators can observe students' skills in connecting current knowledge with previous knowledge to be processed into a new knowledge.

STEM learning has been recognized for its positive impact on developing higher-order thinking skills among students. Sarwi *et al*. [47] highlights that STEM application is highly suitable for science learning, enabling students to apply their knowledge to design solutions for environmental issues using technology. These points out that STEM learning has a positive effect on student learning outcomes, particularly in the concept of evolution [48]. The result concludes that STEM learning contributes to improved creative thinking skills among students [49]. Moreover, STEM-based learning has been shown to boost motivation, provide hands-on engineering experiences, enhance student achievement, and increase creative thinking skills [50], [51]. Project-based STEM approaches have been shown to enhance students' understanding of the importance of science and provide practical problem-solving experiences, contributing to meaningful learning and supporting future career readiness [52], [53]. Overall, the integration of STEM into education has a multifaceted positive impact, including improving critical thinking, problem-solving abilities, and understanding of scientific concepts.

Learning that links science and religion can facilitate reflective thinking and critical thinking. Views, opinions, attitudes, and knowledge will be built by a person through interaction with the socio-cultural context in living history and interpreted as a religion adhered to [54]. There are many verses in the Qur'an that instruct us to think about some of the signs of His greatness and majesty through the creation of the heavens and the earth, as well as various natural phenomena and events [55]. The guided discovery learning model by integrating verses of the Qur'an is generally good, this is shown in the highest student responses found in the fourth statement, namely students are easier to understand concepts in learning with percentages [56]. When the Qur'an is brought into the realm of education, it is a new breakthrough. Teaching using spiritual education in the classroom is expected to produce students with character [57]. The concluded that teaching materials packaged with oral traditions that developed in Balinese society contain character education that can be integrated into natural science material [58]. Spiritual strategy in learning science, namely the strategy of incorporating important points contained in the Qur'an and hadith in learning. This strategy focuses on guiding students to establish connections between the scientific knowledge they acquire and the fundamental principles of Islam. The objective is to encourage students to relate each scientific

concept to their daily experiences, comprehend the essence of the material, and effectively apply it in various aspects of their lives [59]. Two studies [15], [60] affirm that integrating Islamic values into science learning leads to improved academic performance among junior high school students. Additionally, utilizing the Al-Qur'an mathematics interconnection approach in learning demonstrates a positive impact on student learning outcomes [59]. Integrating science learning with Islamic values offers students an opportunity to link scientific knowledge with their Islamic beliefs and personal experiences. During secondary education (junior high school), it is opportune to instill character education and cultivate the belief that science and religion are inseparable entities, emphasizing this unity to students.

5. CONCLUSION

According to students, science holds paramount importance as a foundation for advancing their education, a tool for conducting everyday activities, and a means to revive the legacy of Islam through its historical contributions to the field. Moreover, a good teacher, from a student's perspective, embodies qualities such as making learning enjoyable (fun learning), using creative teaching methods, instilling motivation, establishing connections between science and religion, engaging in investigative activities, incorporating humor, and effectively relating science to everyday life. These attributes collectively contribute to what students perceive as an ideal and effective educator. Furthermore, distinctions in reflective thinking and critical thinking abilities were observed between the experimental class and the control class. Learning that connects science and Islamic religion and examines STEM-R aspects is able to develop students' thinking skills.

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