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Challenges and Opportunities in Implementing Integrated STEM Education in Science Learning at Islamic Junior High Boarding Schools

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ABSTRACT

This study explores the challenges and effectiveness of implementing Integrated STEM Education in lower secondary schools within Islamic boarding schools (pesantren). A quasi-experimental method was employed using a one-group pre-test and post-test design, along with observation. The study involved 89 students from boarding schools-based junior high schools. Qualitative analysis of learning challenges was conducted through data reduction, categorization, and synthesis, while the effectiveness of learning was measured using a paired sample t-test and Cohen's d for effect size. The findings reveal that students faced several obstacles during the implementation of STEM education, primarily due to the dense schedule of boarding schools activities. These led to physical fatigue, lack of focus, and drowsiness in class. Female students were generally more active in class but experienced greater learning difficulties compared to male students, who struggled more with group communication. Despite these challenges, Integrated STEM Education showed great potential. Statistical analysis demonstrated a highly significant effect ($t = -23.4$; $\alpha = 1.66$; $p < 0.001$), indicating that with adequate support, resources, and time management, STEM education can be an effective strategy to enhance educational quality in the boarding schools context.

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1. INTRODUCTION

Islamic boarding schools are educational institutions that offer students residential facilities in the form of dormitories. These schools encompass several key elements, including the "Kyai," who serves as a teacher, educator, and role model. Students, known as Santri, learn from the Kyai, while the mosque serves as both an educational space and a venue for congregational prayers, and the dormitory provides accommodation for the students. What sets Islamic boarding schools apart from other educational institutions is their unique social role within the community, characterized by the presence of the Kyai, the independence of the students, and the strong social connections that form among alumni (Shodiq, 2023).

The education system in Islamic boarding schools possesses distinct characteristics when compared to public schools, primarily because learning occurs within the environment of the boarding school itself. This type of educational approach aims to foster improved personality development and independence among students. The changes implemented extend beyond mere knowledge enhancement; they also encompass the attitudes, morals, and character of the students (Zawawi, 2013). While understanding and knowledge are crucial in the learning process, character development holds equal significance in Islamic boarding schools (Chandra, Marhayati, & Wahyu, 2020). One of the primary venues for character formation within these institutions is the dormitory. The traits fostered in Islamic boarding schools include religiousness and tolerance (Cahyaningrum, Sudaryanti, & Purwanto, 2017). Students cultivate these religious and tolerant characteristics through various practices, such as greeting Ustadz and peers, praying together in the mosque, engaging in dhikr and collective prayers, reciting the Qur'an, fasting on Mondays and Thursdays, and adhering to a queuing culture during ablution (wudhu) (Chandra, Marhayati, & Wahyu, 2020).

The applied model of boarding school education offers several advantages over traditional general education. Boarding schools education integrates theory and practice to shape students' character, discipline, and life skills. This integration is implemented through several key activities: 1) The study of kitab kuning deepens students' religious understanding and encourages its application in daily life; 2) Daily worship practices instill spiritual discipline, while social activities such as khidmah foster empathy and social responsibility; 3) Halaqah sessions train students in critical thinking and collective decision-making through discussion and dialogue; 4) Leadership development is fostered through student organizations, while life skills are enhanced through entrepreneurship training. Additionally, public speaking exercises help strengthen students' communication abilities. Through this comprehensive process, boarding schools produce graduates who are not only knowledgeable, but also spiritually and socially mature. Through these various activities, boarding schools education provides a holistic environment for students' growth, integrating knowledge, practice, and character in a balanced manner. As a result, boarding schools graduates are expected to be not only academically competent, but also spiritually, socially, and emotionally mature in facing life's challenges. Every element of the boarding school education model plays an active role in the educational experience, focusing on fostering strong socio-religious values, cultivating national awareness, and promoting respect for diversity—especially given that students come from a wide range of social, economic, cultural, and academic backgrounds, resulting in a high degree of heterogeneity among dormitory residents (Maksum, 2015). Furthermore, Islamic boarding schools provide a secure environment that protects students from negative influences such as free association, drug use, gang violence, and other detrimental activities. This is achieved by ensuring that students are monitored around the clock within the boarding school setting (Hendriyenti, 2014), allowing staff to oversee all student activities effectively.

Students in Islamic boarding school dormitories live independently, managing their daily needs such as washing clothes, eating, and handling finances, as well as engaging in academic activities without parental guidance. Within the dormitory setting (Maksum, 2015; Nabella, 2017), students are expected to comprehend the subject matter and apply it in real-life situations (Nabella, 2017). However, they encounter several obstacles, including the challenge of grasping the material presented by teachers or ustads, which is often not easily understood (Basyaruddin & Khoiruddin, 2020). Additionally, their schedules are filled with activities from morning until night, which can lead to feelings of boredom during study sessions and a subsequent decline in motivation to learn. This monotony can foster laziness and exhaustion, particularly as study durations extend (Jannah, Raihana, & Ali, 2019). Furthermore, the regulations in Islamic boarding schools limit the use of the internet, cell phones, and computers, which can hinder students' ability to fully engage with learning materials through diverse approaches. Exploring alternative methods in the learning process may help enhance students' understanding of the content.

The application of learning to students in the current era also requires a learning approach that can encourage students to be more active in asking questions and make it easier to understand lessons, not only being required to memorize and accumulate information without knowing whether students have understood or not (Mesihanti, 2022). The STEM approach is one way to make the learning process more connected and relevant for students, especially junior high school students. The integrated STEM education approach involves students working collaboratively to create a solution to a problem. The integrated STEM education approach will indirectly require students to think critically in solving problems and to find the right solution as according to the problems they face (Tati., 2017). Two major processes in integrated STEM education learning are scientific inquiry and engineering design process. In the scientific inquiry learning process, students are faced with scientific investigations into a scientific phenomenon related to biodiversity to find basic knowledge about the causes of these events (Meester, et al., 2021). In the engineering design process, students apply the knowledge gained in scientific inquiry for finding to find solutions to problems or do simple experiments related to the sub-concept.

During the engineering design process, students can practice their technological skills (technology literacy) to use the tools and materials around them as something useful or to find information in the engineering design. In addition, in the engineering design process, students are trained to use their mathematical abilities (mathematical thinking) in solving problems, evaluating simple experiments that have existed, planning steps effectively in making simple experiments, and ending with making solutions (Vasquez, et al., 2013).

Understanding students' difficulties and obstacles in learning, as well as their responses, is crucial for improving education, particularly in integrated STEM education. Difficulties refer to the challenges encountered during the learning process. Some of the key obstacles include motivation, curriculum design, skills development, inadequate facilities, student engagement, and environmental factors (Ramli & Talib, 2017). These obstacles often lead to negative responses from students during their learning experiences. Research focusing on learning within Islamic boarding schools remains limited. Notable studies include those exploring the education system in Islamic boarding schools in Indonesia (Junaidi, 2016), learning strategies and challenges during the Covid-19 pandemic (Abdurrohim, 2022), and the development of teaching materials for maharah kalam (Ritonga, Zulpina, & Darman, 2022). Other research has addressed environmental education in these schools during the pandemic (Hidayati,

2020), the role of homeroom teachers in promoting learning discipline (Syahrani, 2020), and the importance of character-building educational institutions (Syafe'I, 2017; Candra et al., 2020) in Islamic boarding schools (Fauzi & Hosna, 2022), as well as STEM initiatives at Al-Qodiri Islamic boarding school (Rena, 2018). However, educational research pertaining to Islamic boarding schools is challenging to locate, especially regarding the specific difficulties or obstacles students face, their responses, and the effectiveness of learning as it relates to implementing integrated STEM education in junior high schools and MTs in Jember Regency.

2. RESEARH METHODE

The research conducted in this study is quasi-experimental, employing a one-group pre-test, post-test, and observational design. The results of the tests aim to identify the challenges and opportunities of Integrated STEM Education in environmental schools within Islamic boarding schools in Jember Regency. This research was carried out during the even semester of the 2022/2023 academic year, specifically in August 2023, across four meetings. The first meeting focused on understanding the material related to environmental pollution and project planning. The second meeting involved hands-on project work. During the third meeting, participants worked on filling out LKPD assignments and presented their findings. The final meeting consisted of completing questionnaires, post-tests, and conducting interviews.

Participants

The population in this study consisted of junior high school students and students from Islamic boarding schools (MTs) in the Jember Regency. The sample included three schools, specifically two junior high schools and one Islamic boarding school, with each school representing one class. The classes studied were Junior High School Nuris Jember (grade 7H), Junior High School Darus Sholah (grade 7A), and MTs Unggulan Al-Qodiri (class 7C). The distribution of male and female students varied among the schools. This grouping was influenced by regulations within the Islamic boarding school, which require the separation of male and female students. In total, there were 89 participants in the study. The distribution of participants by gender is shown in Table 1.

Table 1. Participants per school

Participants	**Gender**			
	N	**P**	**N**	**L**
School I	32	100%	0	0%
School II	12	44,4%	15	55,6%
School III	0	0%	29	100%
Total	44	49,4%	45	50,6%

Research Procedures

This research is conducted in accordance with the research procedures that had been created. The research procedure can be seen in the figure below.

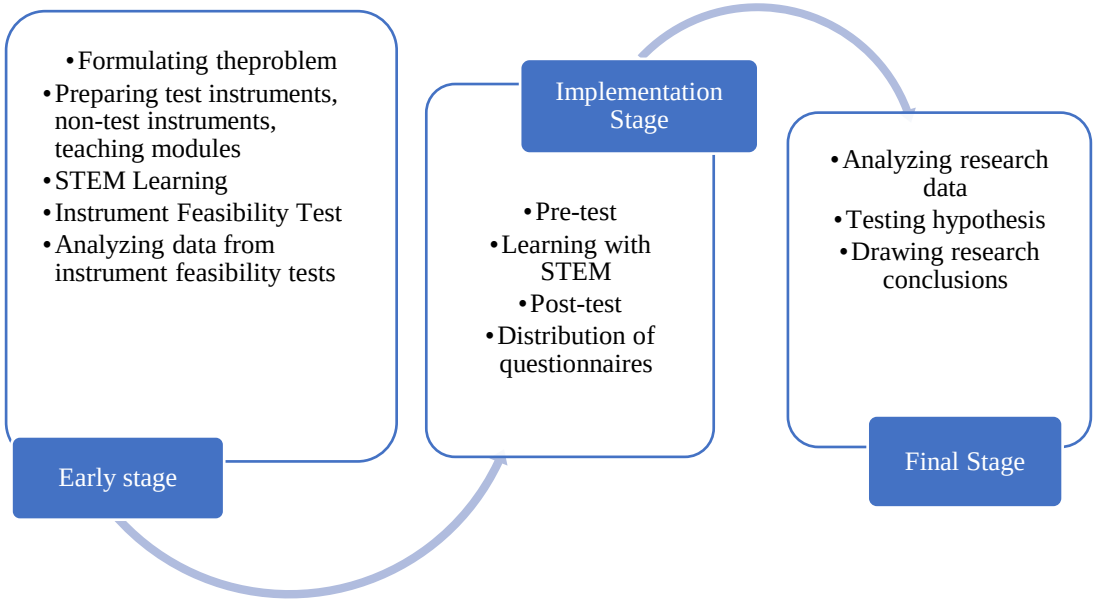

Figure 1. Research Procedure

The research procedure is divided into three stages, namely the initial stage, the implementation stage, and the final stage. The initial stage is 1) formulating the problem. 2) Compiling test instruments, non-test instruments, and teaching modules. The test instruments are compiled based on aspects in the RPP (teaching plans) such as opportunities and challenges of Integrated STEM education in Islamic boarding schools. Non-test instruments are compiled with aspects regarding student responses to the application of the integrated STEM education approach in science subjects. 3) Instrument feasibility test. 4) Analyzing data from the results of the instrument feasibility test. The next stage is implementation, namely 1) filling out the pre-test, 2) STEM learning. STEM learning in junior high schools and MTs in Science subjects are given on environmental pollution material in the odd semester. The material is carried out by inviting students to use STEM learning to make a simple water filtration device. The tools and materials in the manufacturing process have been provided so that students can immediately create a water filtration device. Each group is given a Student Worksheet (LKPD) which is worked on with their respective groups. The project work begins with activity planning and selection of tools and materials, and project implementation begins with purchasing tools and materials from the seller according to the initial capital given to Rp. 20.000. After that, students make a simple water filtration tool and test it. Then each group filled out the LKPD and presented the results of their experiments to the class. 3) Fill out the post-test, 4) complete the questionnaire, and 5) interviews. Interviews were conducted with 6 students from each class consisting of 3 active students and 3 less active students. The final stage consists of: 1) analyzing research data and 2) drawing research conclusions. The data that has been tested for hypotheses is then concluded.

Data analysis

The collection and analysis of this research data were carried out in several ways according to the formulation of the problems that have been explained:

a. Data on the difficulties and challenges of integrated STEM education were analyzed qualitatively. First, data reduction is data obtained during the research process (through observation, questionnaires, and interviews), which will be selected first so that a clearer picture is obtained and more focused on the initial objectives of the research. Data reduction is carried out by: a) identifying units. Initially, a unit was identified, namely the smallest part found in the data that has meaning when associated with the research problem, and b) after the unit is obtained, the next step is to create a code, meaning giving a code to each unit, so that the data or unit can still be traced, from which source. Data reduction in research, for example, simplifies the information obtained through a theoretical understanding of environmental pollution learning materials or mastery in working on water filtration projects. This statement can be reduced to one point: understanding the concept. The next step is categorization, carried out with the following steps: a) compiling categories, categories are efforts to select each unit into parts that have similarities, and Each category is given a name called a label. Categorization in this study, for example, there are too many

choices of tools, students do not know the order and function of the layers of water filtration that they will make, the high price of materials compared to the capital provided. Some of these known difficulties are categorized into activity planning. The last way, synthesis is carried out with the following steps: a) synthesizing means finding a relationship between one category and another, and b) the relationship between one category and another is given a name or label again.

b. test determines the opportunities for implementing integrated STEM education for students in secondary schools (SMP and MTs) Islamic boarding schools in Jember. This test is done by analyzing the pre-test & post-test learning outcomes. The analysis was carried out with a paired sample T-test (parametric) difference test. In addition, a Cohen d effect size test was also conducted to determine the effectiveness of implementing integrated STEM education in Islamic boarding schools in Jember

3. RESULT

This study is a quasi-experimental study with a one group pre-test-post-test design to determine the challenges and opportunities of integrated STEM education in science learning in junior high schools and Islamic boarding school MTs. The schools studied were class 7 H of SMP Nuris, class 7A of SMP Darus Sholah, and class 7C of MTs Unggulan Al-Qodiri. The division of groups in each school was different: SMP Nuris had 6 groups, SMP Darus Sholah had 4 groups, and MTs Unggulan Al-Qodiri had 5 groups. The research procedure used included 3 stages consisting of the initial stage: formulating the problem, compiling test instruments, non-test instruments, teaching modules, instrument feasibility testing, and analyzing instrument feasibility testing. Furthermore, the implementation stage starts with the pre-test, integrated STEM education, post-test, and the distribution of questionnaires, and interviews.The final stage is analyzing data according to the research objectives.

3.1 Difficulties and Challenges of Integrated STEM Education in Islamic Boarding Schools

This study uses a quasi-experimental method with one group pre-test-post-test, where students will receive STEM treatment in their learning process. The difficulties and challenges of Islamic boarding school students with Integrated STEM Education are studied through distributing questionnaires and interviews to see student responses and interviews are conducted with several students to find out deeper reasons for their challenges and difficulties

a. Student Response

The questionnaire was distributed to determine the difficulties and obstacles students felt during learning and project work in class. This questionnaire contains open-ended questions about the difficulties and obstacles students felt during learning and project work. The questionnaire was distributed to students after they had completed the post-test sheet. The results of the questionnaire distribution can be seen in Figure 2 and Table 2.

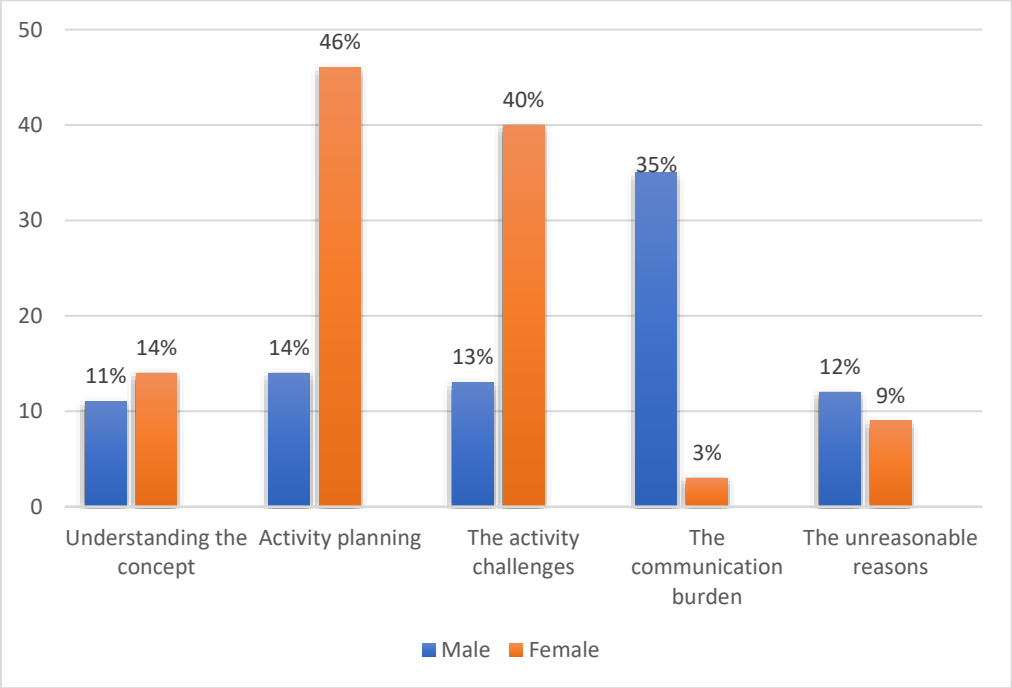

Figure 2. Difficulties and obstacles to integrated STEM education at the junior high school level

Learning about STEM in Islamic boarding schools with environmental pollution material with a water filtration tool making project for 3 meetings. Figure 2 shows that female students have more difficulties and obstacles than male students. Specifically, male students struggle most when communicating with group members. Conversely, when understanding concepts, planning activities, and implementing projects, the most difficulties are experienced by female students. This is because female students are more active in class but also experience more difficulties.

Table 2. Student Learning Difficulties to STEM education in Islamic boarding school environments

No.	Student Learning Difficulties	Presentation
1.	Understand the concept	15,2%
2.	Activity planning • Too many choices of tools and materials • Do not know the order and function of each layer • The price of materials is expensive compared to the capital provided	39,3%
3.	The activity challenges • Assembling the layers of water filtrati on equipment • The choice of materials is very large, but the opportunity to choose materials is limited.	23.1%
4.	The communication burden	12,3%
5.	The unreasonable reasons • Feeling sleepy in class • Feeling weak because of hunger • Lack of focus and confusion in class • Feeling tired because of many activities at the Islamic boarding school • Group members contribute less	10,1%
	Total	100%

Integrated STEM education treatment in junior high school students found several learning difficulties, namely difficulty in understanding concepts, activity planning, project implementation, communication with group members, and unreasonable reasons. In general, both male and female students had the most difficulties felt during activity planning as much as 39.3% and the least with unreasonable reasons as much as 10.1%. Activity planning is considered difficult for students because this process requires a good basic understanding in order to complete the project. However, students in Islamic boarding schools experience several obstacles in obtaining information so that their understanding is less supportive in classroom learning. Then, it was discovered that there were unreasonable or unique reasons presented by students in interviews such as students feeling sleepy in class, weak because of hunger, lack of focus and confusion in following classroom learning, and feeling tired due to daily activities in Islamic boarding schools, as well as minimal group contribution in the process of working on group assignments. Several difficulties that have been described cause the learning process to be less than optimal.

b. Data Triangulation Through Interviews

After distributing the questionnaire, an interview was conducted. This interview aims to learn more about the problems felt by students in the field in more depth. The interview was conducted in class 7H of SMP Nuris Jember, class 7A of SMP Darus Sholah Jember, and class 7C of MTs Unggulan Al-Qodiri with 6 students in each class, consisting of 3 active students and 3 other students who were less active. The results of the interviews with students can be seen in Table 3.

Table 3. The interview results

No.	Statement of problems	Indicators	Result
1.	The difficulties experienced bu students	The understanding of learning material	Students stated that the material taught was easy to understand. However, the project work process was considered difficult due to a lack of understanding of the correct function, composition and result.
		The tools anda materials used (learning aids)	Students feel that there are too many tools and materials to choose from to make a water filtration device, making it difficult to choose the tools and materials according to their needs based on their function.
		The project completion	The student project results showed that only 1 group from each class made the water filtration tool correctly
2.	The common problems of the students	The density of Islamic boarding school activities	The activities of the Islamic boarding school are numerous from morning before dawn until night, causing students to have less rest and little time to study material from public schools.

STEM learning in junior high schools in Islamic boarding schools can be concluded that students experience difficulties and obstacles. Table 3 shows the results of student interviews. The first difficulty experienced by students is understanding the concept of environmental pollution material and its relationship to the real problems given, then understanding the project to make a water filtration device as a solution to the problem topic discussed. The second difficulty is project planning, some students said it was difficult to plan well because they were the first time they had done STEM learning systematically from selecting the tools and materials to adjusting to the capital given. The third difficulty was during the implementation of the project. Most students stated that the implementation of the project was very fun to do. However, the result was only one group that managed to filter the water correctly. The failure of the project made students even more challenged to experiment until they succeeded. Then, students also experienced obstacles during the learning process due to the many activities of the Islamic boarding school that took place from morning to night. These activities include congregational prayer, manaqib, interpretation, qosidah, and memorization of the Qur'an. This causes students to have very little time to study the material. In addition, Islamic boarding schools also have strict regulations regarding the use of mobile phones and computers. At the same time, the internet is one of the things that makes integrated STEM education easier for independent learning preparation.

3.2 Learning Effectiveness Test

Integrated STEM education is applied to science learning on environmental pollution material with a project to make a simple filtration device, then its effectiveness is tested by looking at the influence of STEM applications on 7th grade students of junior high schools and Islamic boarding schools in Jember. The effectiveness test on students is carried out by giving a pre-test before working on the project and a post-test after students complete the project. The time for giving the pre-test and post-test is 3 weeks. The first week a pre-test is given to measure students' knowledge about before working on the project and planning the project, then in the following week, the students work is on a project to make a simple filtration device in groups, and the last week students work on LKPD questions and post-tests. These results can be seen in Table 4.

Table 4. Comparison of pre test-post test results

Participant	N	Mean				t	df	*d*	*α*
		Pre-test	Std. deviasi	Post-test	Std. deviasi				
School I	30	49,83	7,82	65,00	11,14	-14,7	29	1,57	< 0.001
School II	31	49,84	11,29	73,39	12,13	-14,5	30	2,00	< 0.001
School III	28	44,46	11,16	63,93	13,70	-17,674	27	1,55	< 0.001
Total	89	48,15	10,40	67,58	12,92	-23,4	88	1,66	< 0.001

Steps to determine significant differences between pre-test and post-test learning outcomes using the t-test. From the t-test conducted as a whole, the calculated t value was obtained -23.4, while the negative sign indicates a difference in value between the pre-test and post-test values. The significant value of the t-test was obtained at less than 0.001, the value is less than 0.005.

Based on these data, a decision was made if the alternative hypothesis was accepted, namely that there was a significant difference between student learning outcomes before and after being given STEM treatment. Based on these data, an analysis of student understanding was then carried out after being given STEM treatment. Integrated STEM education was carried out by students in the form of a water filtration device design project was carried out in groups. Then the pre-test and post-test results from the male and female genders are shown in the table below.

Table 5. The Comparison of pre-test-post-test results based on gender

Partisipan	**N**	**Mean**				**t**	**df**	***d***	***α***
		Pre-test	**Std. deviasi**	**Post-test**	**Std. deviasi**				
Male	45	46,22	10,82	67,67	13,55	-20,2	44	1,74	< 0.001
Female	44	50,11	9,67	67,50	12,42	-14,35	43	1,56	< 0.001

The role of gender in integrated STEM education for junior high school students in Islamic boarding schools based on the results of statistical analysis has the same significance value between male and female gender of 0.001, where the value is less than 0.05. So it can be concluded that both male and female genders influence student learning outcomes of STEM treatment. Statistical analysis results cannot be used as the only basis for conclusions because other factors influence, such as the student's learning environment, especially in Islamic boarding schools.

4. DISCUSSION

This study focuses on the challenges and opportunities of implementing integrated STEM education in science learning on environmental pollution material in junior high schools and Islamic boarding school MTs. The discussion of research results is based on field observations, analysis of the data obtained, and comparison of the results obtained with previous studies.

4.1 Difficulties and Challenges of Integrated STEM Education in Islamic Boarding Schools

The difficulties and obstacles in STEM learning in this study proved that female students had more difficulties and obstacles than male students. Psychologically, women tend to show more interest in something. However, they also experience more difficulties. A study at Cornell found that although active learning methods provide general benefits for students, males participate more often in class discussions than females. However, females show greater concern for their gender identity and face more anxiety related to gender stereotypes, which can hinder their active participation in class (Cornell, 2020).

A meta-analysis showed that although females often have high academic motivation, they are also more susceptible to test anxiety and gender stereotypes that can affect their learning outcomes. On the other hand, males are more likely to have higher self-confidence in subjects such as mathematics and science, which are often influenced by social stereotypes (Frontiers, 2022). Self-efficacy plays a significant role in academic success, but women often feel less confident in STEM tasks, which can limit their engagement. Research suggests that increasing support and gender-friendly learning environments can boost women's self-confidence and improve their participation in these fields (Frontiers, 2022). The most common difficulty experienced by men in this study was when communicating with group members.

Men's difficulties in expressing emotions are often caused by psychological and social factors, such as gender norms emphasizing stoicism and assertiveness. This can lead them to tend to suppress emotional expression and rely more on individual rather than relationship-based emotion regulation strategies. Studies have shown that men often experience higher levels of avoidant attachment than women, due to social learning that emphasizes the inadmissibility of showing vulnerability or soft emotions (Ackley, 2016).

Further research has also found that emotional intelligence (EI) plays a significant role in men's psychological well-being. For example, males with high levels of EI tend to have better abilities in managing stress and improving their psychological health. One study suggests that emotion regulation training to improve EI may be more beneficial for males than females, as it helps them be more open in recognizing and expressing emotions (Malinauskas & malinauskiene, 2020).

Overall, the results of the study showed that both male and female students experienced the most difficulties during STEM activity planning. Other studies also indicated similar results that STEM learning improves overall student learning outcomes. However, barriers such as group coordination, scheduling, and integration of STEM concepts often arise, especially in the project planning phase (Ribeirinha, Baptisa, & Correia, 2024).Regarding the gender, these difficulties did not differ significantly between males and females in STEM-based academic achievement, although learning strategies such as STEM PjBL can narrow the gender gap in learning outcomes. However, factors such as gender stereotypes and the influence of the social environment also affect student motivation and engagement, especially in the long term (Reinking & Martin, 2018).

Several studies have shown that women often face social and structural barriers, such as gender stereotypes that limit their confidence in STEM fields. In contrast, men tend to be more supportive of exploring STEM fields early on. Research by Lim et al. (2021) discusses how international female students, especially in STEM postgraduate programs, face complex challenges, including gender marginalization. In addition, research by Kans and Claesson (2022) found gender-related differences in academic interests and emotions in STEM learning among high school students in Sweden.

Planning activities in STEM-based learning is often considered difficult for students because it requires a strong understanding of basic concepts to complete the project successfully. Other studies have shown that planning activities in project-based learning, especially in STEM (science, technology, engineering, and mathematics), is often challenging for students due to inadequate resources and guidance. (Hu et al., 2023 & Aldabbus, 2018). This is because the process requires a strong foundational understanding and critical thinking skills. Students in Islamic boarding schools face additional challenges, such as limited access to relevant information and learning resources, which can hinder their understanding of project-based learning.

Another study also highlighted that STEM integration in faith-based educational settings, such as Islamic boarding schools, requires a specific approach to adapt the methodology to the local cultural context and curriculum (Shamsi, 2024). One recommendation is to provide intensive training to teachers to support students in designing and implementing STEM projects effectively. A study in the Journal of Education and Practice explained that students need more support in the early stages of project planning, especially to understand how to integrate basic concepts into practical solutions. Limited infrastructure and access to technology in Islamic boarding schools are also major barriers to implementing effective STEM programs. Another article in the International Journal of STEM Education discussed that project planning challenges are often compounded by the lack of teacher guidance in developing specific steps for STEM-based projects. This suggests that specific training for teachers in Islamic boarding schools is essential to help students navigate the complex planning stages.

4.2 Learning Effectiveness

Integrated STEM interventions, especially through Project-Based Learning (PjBL), have been shown to have a long-term impact on students' understanding of science concepts. Akhmad et al. (2019) noted a

significant increase in students' critical thinking skills after implementing STEM-PjBL, while Siew & Ambo (2018) found an increase in the scientific creativity of fifth-grade students through a similar approach. Uden et al.

(2023) added that this approach, if supported by neuroscience principles, can increase students' self-confidence, motivation, and belief in science more effectively than traditional methods. A long-term study by Archer & DeWitt (2021) showed that involvement in science projects for 6 months to 3 years can build students' interest and confidence, as well as increase their chances of continuing their education in STEM. Overall, STEM-based learning is not only effective in the short term, but also strengthens understanding, builds motivation, and fosters students' career orientation in STEM.

A systematic review conducted by Le, Nguyen, and Nguyen (2023) found that an integrated STEM approach positively impacts on student achievement, especially regarding learning motivation and critical thinking skills. This study emphasizes that well-planned STEM education provides students with opportunities to understand the world a more integrated, compared to learning that separates subjects.

Research on the role of gender in STEM learning shows that gender factors can significantly affect student learning outcomes. For example, women often face barriers related to social stereotypes that can reduce their confidence and motivation to pursue STEM fields. Meanwhile, men tend to feel more confident in certain areas but may be less engaged in the stronger collaboration aspects required in STEM projects.

Master and Meltzoff (2020), who found that a sense of belonging plays motivates women and minority groups to engage in STEM. A socially supportive environment can increase female students' participation in these fields (Source: Journal of Experimental Child Psychology).

Gender roles in STEM learning in Islamic boarding schools can significantly affect student learning outcomes. This is related to differences in perceptions, motivations, and interactions between male and female students during the learning process. For example, research shows that women are often more motivated to participate in STEM tasks than men, but they also face challenges such as gender stereotypes or limited access to certain resources.

Research on gender roles in STEM learning in Islamic boarding schools shows that this factor can affect student learning outcomes. In the context of Islamic boarding school education, gender roles are often related to traditional values that shape learning patterns. However, when Islamic boarding schools began to adopt STEM approaches, such as project-based learning (PjBL), there was potential to improve learning outcomes, especially in terms of critical thinking, problem solving, and scientific literacy.

In Islamic boarding schools, STEM learning with a gender equality perspective can be implemented through an inclusive approach. This includes providing equal opportunities for male and female students to actively participate in experimental or technology-based learning (Andrianti & Sugandi, 2022).

For Islamic boarding schools, integrating gender equality in STEM education can be a strategic step to produce graduates who are competent in science and technology and able to compete globally. This is also aligns with educational efforts based on moderate and progressive Islamic values (Fadillah, et al. 2024).

Several studies show that learning in Islamic boarding schools has begun to adopt gender equality values. This is implemented by equally involving male and female students in science and religion-based education programs. This study was conducted in a mixed class containing male and female students. This approach aims to improve motivation and learning outcomes in both gender, especially in STEM subjects which previously tended to be dominated by male students. Research involving male and female students in modern Islamic boarding schools shows that the boarding-based Islamic boarding school environment is uniquely build learning motivation. Both male and female students can achieve high learning outcomes when supported by relevant learning and by the needs of the times.

5. CONCLUSION

The results of the study revealed that the implementation of Integrated STEM Education in junior high schools and Islamic boarding school MTs still faces various challenges, especially from the students' perspective. Interestingly, female students were recorded as being more active during the learning process but also experienced more difficulties than male students. Meanwhile, male students tended to experience obstacles in terms of group communication. In general, the main obstacles faced by students came from the dense activities in Islamic boarding schools, which had an impact on their physical condition and concentration while studying. Symptoms such as drowsiness, weakness, and lack of focus became obstacles in creating optimal learning. However, STEM-based learning in Islamic boarding schools showed great potential. Based on the effectiveness test conducted, the

Integrated STEM approach proved to be very effective to implement, with significant results ($t = -23.4$; $\alpha = 1.66$; $p < 0.001$). This shows that, with the right support and strategies, STEM learning can be a potential method to improve the quality of education in Islamic boarding schools.

Based on the results of the study, STEM-based learning in Islamic boarding schools still faces a number of challenges. In addition to limited access to the internet and technological devices, the lack of supporting resources and the lack of adequate guidance also become obstacles in the implementation of integrated STEM education. This study recommends several strategic steps, such as adjusting the schedule of Islamic boarding school activities so that students have sufficient rest time, increasing access to learning resources such as books and technology, and training teachers to be better prepared to assist students in completing STEM-based tasks. In addition, future research is recommended to involve a wider population so that the findings are more representative and applicable.

6. REFERENCES

Ackley, D. (2016). Emotional Intelligence: A Practical Review of Models, Measures, and Applications. *Consulting Psychology Journal*, *68*(4), 269–286. https://doi.org/10.1037/cpb0000070

Akhmad, Y., Masrukhi, M., & Indiatmoko, B. (2020). The effectiveness of the integrated project-based learning model STEM to improve the critical thinking skills of elementary school students. Educational Management, 9(1), 9-16.

Al Shamsi, I. R. (2024). Optimizing STEM Education Via E-Learning: Addressing Challenges and Strategic Planning for Graduate Employment Outcomes. *Emerging Science Journal*, *8*(Special Issue), 231–248. https://doi.org/10.28991/ESJ-2024-SIED1-014

Aldabbus, S. (2018). Project-Based learning: Implementation and Challanges. *International Journal of Education, Learning and Development*, *6*(3), 71–79.

Archer, M. O., & DeWitt, J. (2020). Thanks for helping me find my enthusiasm for physics! the lasting impacts research in schools projects can have on students, teachers, and schools. Geoscience Communication Discussions, 2020, 1-28

Ardwiyanti, D., Prasetyo, Z. K., & Wilujeng, I. (2021). STEM Research Trends in Indonesia: A Systematic Literature Review. *Journal of Science Education Research Journal*, *2021*(1), 38–45. www.journal.uny.ac.id/jser

Ayu, H. D., Alfianda, F. V., Sabrina, F., Prameswari, I., Putri, A. N., & Hudha, M. N. (2023). Systematic literature review: Project-based learning terintegrasi dengan STEM. Wiyata Dharma: Jurnal Penelitian dan Evaluasi Pendidikan, 11(2), 89-106.

Bornette, G., Henriot, C. P., & Arthaud, F. (2024). Effects of A Decennial Spate Flood on Substrate and Aquatic Vegetation of Riverine Wetlands. *Aquatic Botany*, *194*(June), 103789. https://doi.org/10.1016/j.aquabot.2024.103789

Chandra, Pasmah, Nelly Marhayati, and Wahyu Wahyu. "Pendidikan Karakter Religius Dan Toleransi Pada Santri Pondok Pesantren Al Hasanah Bengkulu." *Al-Tadzkiyyah: Jurnal Pendidikan Islam* 11, no. 1 (2020): 111–32.

DIENYE, H. E. (2017). Distribution and Abundance of Aquatic Plants of Oyan Lake, Ogun State, Nigeria. *Bonorowo Wetlands*, *7*(1), 11–15. https://doi.org/10.13057/bonorowo/w070104

Fadillah, M. A., Hirahmah, A., Puspita, S., Jannati, R. P., Padang, U. N., Padang, K., Asahan, M. A. N., Asahan, K., Guppi, M. A. S., Pematangsiantar, K., Stem, M., Menengah, S., & Sma, A. (2024),. *12*(2), 122–131.

Hesti, D., Irawan, A., & Inderia Sari, L. (2023). The Relationship Between Mega Bivalve Abundance and Seagrass Density in Teluk Balikpapan Kalimantan Timur Article Info Abstract Abstrak Kata Kunci. *Tropical Aquatic Sciences*, *2*(2), 140–152. https://doi.org/10.30872/tas.v2i2.546

Higashi, G., & Nishimoto, R. T. (2007). The Point Quadrat Method : A Rapid Assessment of Hawaiian Streams. *Bishop Museum Bulletin in Cultural and Environmental Studies*, *3*(Biology of Hawaiian Streams and Estuaries), 305–312. http://hbs.bishopmuseum.org/pubs-online/strm/23-Higashi-Nishimotor.pdf

Kholiya, D. (2018). *Analyzing The Water Quality and Effects of Aquatic Plants*. *4*(3), 574–578.

Kırım, B., Çoban, D., & Güler, M. (2014). Floating Aquatic Plants And Their Impact on Wetlands in Turkey. *2nd International Conference - Water Resources and Wetlands*, *2013*, 102–109. http://www.limnology.ro/water2014/proceedings.html

Le, H. C., Nguyen, V. H., & Nguyen, T. L. (2023). Integrated STEM Approaches and Associated Outcomes of K-12 Student Learning: A Systematic Review. *Education Sciences*, *13*(3). https://doi.org/10.3390/educsci13030297

Le, H. C., Nguyen, V. H., & Nguyen, T. L. (2023). Integrated STEM approaches and associated outcomes of K-12 student learning: A systematic review. Education Sciences, 13(3), 297.

Malinauskas, R., & Malinauskiene, V. (2020). The Relationship Between Emotional Intelligence and Psychological Well-Being among Male University Students: The Mediating Role of Perceived Social Support and Perceived Stress. *International Journal of Environmental Research and Public Health*, *17*(5), 1–16. https://doi.org/10.3390/ijerph17051605

Master, A., & Meltzoff, A. N. (2020). Cultural Stereotypes and Sense of Belonging Contribute to Gender Gaps in STEM. *International Journal of Gender, Science and Technology*, *12*(1), 152–198.

Nusantara, P. A. (2022). *SETARA : Jurnal Studi Gender dan Anak untuk Mencapai Kesetaraan Gender serta Memberdayakan semua Perempuan*. *4*(02), 143–159.

Obery, A., & Queen, M. (2024). Making the Case for Elementary Biomedical Education in Rural Communities. *Journal of STEM Education: Innovations and Research*, *25*(1), 5–12. https://www.jstem.org/jstem/index.php/JSTEM/article/view/2652

Patel, D. K., & Kanungo, V. K. (2012). Comparative Eco-Physiological Potential of A Submerged and A Free Floating Aquatic Plant to Treat Domestic Wastewater. *Journal of Ecobiotechnology*, *4*(1), 61–67.

Pendidikan di Pondok Pesantren. *Muadiib*, 5(2), 184–207.

Purwaningsih, E., Sari, S. P., Sari, A. M., & Suryadi, A. (2020). The Effect of STEM-PJBL and Discovery Learning on Improving Students' Problem-Solving Skills of The Impulse and Momentum Topic. *Jurnal Pendidikan IPA Indonesia*, *9*(4), 465–476. https://doi.org/10.15294/jpii.v9i4.26432

Reinking, A., & Martin, B. (2018). The Gender Gap in STEM Fields: Theories, Movements, and Ideas to Engage Girls in STEM. *Journal of New Approaches in Educational Research*, *7*(2), 148–153. https://doi.org/10.7821/naer.2018.7.271

Ribeirinha, T., Baptista, M., & Correia, M. (2024). Investigating the Impact of STEM Inquiry-Based Learning Activities on Secondary School Student's STEM Career Interests: A Gender-Based Analysis Using the Social Cognitive Career Framework. *Education Sciences*, *14*(10). https://doi.org/10.3390/educsci14101037

Samsudin, M. A., Md Zain, A. N., Jamali, S. M., & Ebrahim, N. A. (2018). Physics Achievement in Stem Project Based Learning (PjBL): A Gender Study. *Asia Pacific Journal of Educators and Education*, *32*, 21–28. https://doi.org/10.21315/apjee2017.32.2

Sari, L. I. (2023). *Kota Bontang Conditions Seagrass Density and Sediments in the Waters of Selangan Hamlet , Bontang City*. *2*(2), 196–202.

Sölpük Turhan, N. (2020). Gender Differences in Academic Motivation: A Meta-Analysis. *International Journal of Psychology and Educational Studies*, *7*(2), 211–224. https://doi.org/10.17220/ijpes.2020.02.019

Wahono, B., Chang, C., & Khuyen, N. T. T. (2021). Teaching socio-scientific issuses through integrated STEM education; an effective practica; averment from Indonesian science lessons. Internasional Journal of Science Education, hal. 2666-2667.

Wahono, B., Chang, C-Y., & Khuyen, N.T.T. (2021). Teaching socio-scientific issues through integrated STEM education: an effective practical averment from Indonesian science lessons. International Journal of Science Education, 43:16, 2663-2683.

Wahono, B., Lin, P.-L., & Chang, C.-Y. (2020). Evidence of STEM enactment effectiveness in Asian student learning outcomes. International Journal of STEM Education, 7(1), 36.

Wu, B., Hu, Y., Yu, X., Sun, M., Xie, H., Li, Z., & Wang, M. (2023). How Do Secondary Students Engage in Complex Problem-Solving Processes in A STEM Project? *Knowledge Management and E-Learning*, *15*(4), 506–522. https://doi.org/10.34105/j.kmel.2023.15.029

Yu, Z., & Wang, L. (2023). Gender-Moderated Effects of Academic Self-Concept on Achievement, Motivation, Performance, and Self-Efficacy: A Systematic Review. *Frontiers in Psychology*, *14*(1136141). https://doi:10.3389/fpsyg.2023.1136141

Zeng, Z., Yao, J., Gu, H., & Przybylski, R. (2018). A Meta-Analysis on The Effects of STEM Education on Students' Abilities. *Science Insights Education Frontiers*, *1*(1), 3–16. https://doi.org/10.15354/sief.18.re005