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Enhancing science literacy through flipbook-based STEM Qur'an e-modules: a case study in Islamic boarding schools

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This study aimed to evaluate the effectiveness of the e-module in enhancing students' science literacy in secondary schools within Islamic boarding school environments. The research employed an experimental design with a quantitative approach, involving the measurement of students' science literacy through Pre Tests and Post Tests in secondary schools located in a province in Indonesia. The research sample consisted of 150 students from 5 different schools. The data was collected through science literacy tests grouped based on the indicators of scientific inquiry, problem-solving, and scientific reasoning. The application of the STEM Qur'an-based Flipbook e-Module to students' science literacy skills was carried out over 3 sessions per week for 5 weeks. The results showed that the implementation of the STEM Qur'an-based Flipbook e-module led to a significant improvement in students' science literacy. The average Post Test score increased from 35.3–38.9 in the Pre Test to 80.58–80.62 in the Post Test. The analysis revealed that students demonstrated excellent science literacy skills in the scientific inquiry indicator, good skills in the problem-solving indicator, and fair skills in the scientific reasoning indicator. The results of the ANOVA and Post Hoc Test revealed that there were no statistically significant differences among the tested school groups. This indicates that the STEM Qur'an-based Flipbook e-module was equally effective in enhancing students' science literacy across all participating schools.

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Introduction

Scientific literacy is one of the essential competencies in modern education, especially in the era of the Industrial Revolution 4.0, which demands a deep understanding of science and technology (Chen et al. 2019; Nilyani et al. 2023; Oktarina et al. 2023). Scientific literacy encompasses the ability to use scientific knowledge to identify problems, draw evidence-based conclusions, and solve global issues (Yuliati and Saputra, 2020). It is closely related to technological and mathematical literacy (Permanasari, 2016) and includes the understanding of science and its application in daily life (Archer-Bradshaw, 2014; Laugksch, 2000; Putri and Wulandari, 2022; Jamaluddin et al. 2019). However, the level of scientific literacy in many countries, including Indonesia, remains low (PISA, 2018). Although innovative approaches such as problem-based learning have been implemented, students' scientific literacy has not developed optimally (Sulistiyowati et al. 2018). This poses a serious challenge, particularly in boarding schools, where the focus of learning is more dominant on religious studies than science.

Based on observations in a boarding school in one of the provinces in Indonesia, students' scientific literacy skills remain low, primarily due to conventional teaching methods, limited use of technology, and a lack of innovative approaches, especially in physics (Tanjung et al. 2024; Afidah &Sudibyo, 2025). This results in a gap in understanding scientific concepts and problem-solving skills needed in the digital era (Handayani et al. 2018). In fact, scientific literacy is crucial to keep pace with rapid technological advancements (Santos et al. 2023). Therefore, an innovative approach is needed that not only enhances scientific literacy but also aligns with Islamic values.

One innovative approach that can be adopted is STEM, which has proven effective in improving scientific literacy. Numerous studies have shown that the STEM approach is an effective educational innovation for motivating students (Amalina et al. 2025), enhancing scientific literacy (Santos et al. 2023), and helping students compete in the global era by solving problems using technology (Yuliati and Saputra, 2019; Yip, 2020). STEM integrates science, technology, engineering, and mathematics into a single learning process (Pimthong and Williams, 2018), fostering the development of reasoning, literacy, critical thinking, inquiry, problem-solving, and higher-order thinking skills (HOTS) (Çevik, 2018; Struyf et al. 2019; Agussuryani et al. 2022; Teplá and Distler, 2025). Furthermore, STEM-based learning trains students to be more adaptive to global developments and to maximise the use of technology (Artobatama et al. 2023).

The STEM approach will be relevant to learning in boarding schools if it is linked to Islamic values in accordance with the Qur'an. STEMQ (Science, Technology, Engineering, Mathematics, and Qur'an) is an extension of STEM designed to harmonise modern science with the teachings of the Qur'an, which is believed to be a source of universal truth (Farhan, 2023). This approach aligns with the idea of the Islamisation of knowledge proposed by Al-Attas (1979), who emphasised the importance of aligning modern science with an Islamic worldview. The concept of STEMQ was first introduced as a response to the need to harmonise modern science with the teachings of the Qur'an, which is believed to be a source of universal truth (Farhan, 2023).

The STEMQ approach not only integrates science, technology, engineering, and mathematics but also enriches learning with Qur'anic values, which can strengthen students' understanding of tawhid (monotheism) and ethics (akhlak). For example, the concept of light and optical instruments can be linked to QS. An-Nur: 35, which describes Allah as 'Light upon Light' (Nūrun 'alā Nūr). This verse not only explains the physics principles of light but also invites students to reflect on the greatness of Allah as the source of all light, both physical and spiritual. This integration encourages students to view science as a means to understand the magnificence of His creation while developing ethics in the use of technology.

Through STEMQ, students are not only taught to solve scientific problems but also to reflect on the greatness of Allah's creation and develop strong morals and ethics (Ash Sidiq et al. 2024). Thus, STEMQ not only retains the benefits of STEM in enhancing scientific literacy and technological skills but also enriches learning with spiritual and moral dimensions, preparing students to face global challenges with a foundation in Islamic values. This approach also supports the Sustainable Development Goals (SDGs), particularly in quality education (SDG 4) and responsible consumption and production (SDG 12).

One form of digital transformation that supports the SDGs is the use of flipbook-based e-modules in learning. The use of flipbook-based e-modules in STEM learning, supported by information and communication technology (ICT), offers many advantages, such as presenting material in various formats (text, audio, video, images) that can be accessed through electronic media (Dewi and Maulida, 2023; Prihatiningtyas and Alimah, 2021). These e-modules also support independent learning, train students in problem-solving, and enhance their scientific process skills (Prihatiningtyas et al. 2023).

Flipbook-based e-modules also enable more dynamic and interactive visualisation of scientific concepts, strengthening students' understanding by up to 30% compared to textbooks (Rarastika et al. 2024) and improving problem-solving scores from 65.8 to 85.4 (Asshagab et al. 2024). Various studies on the use of STEM-based e-modules assisted by flipbooks have shown positive results in improving students' scientific literacy, both in Indonesia and abroad. In Indonesia, Rahmawati et al. (2021) found that the application of e-modules in the endocrine system subject in problem-based learning improved students' scientific literacy and learning outcomes. Dalaila et al. (2022) also demonstrated that the development of socio-scientific-based e-modules enhanced students' scientific literacy. Herlina and Abidin (2024) investigated various types of e-modules, including Discovery Learning and STEM-based modules, which can improve students' scientific literacy. In Australia, Chan et al. (2020) developed interactive online modules to assess information literacy in the context of Evidence-Based Practice, while in the United States, Otto et al. (2023) showed that teaching methods using peer-review modules strengthened students' disciplinary literacy and scientific identity. In Canada, the University of Toronto used e-modules in online learning to enhance students' scientific literacy, reflection skills, and critical thinking (Fitzpatrick et al. 2021). Although many studies have been conducted on the use of STEM-based e-modules, research combining STEM aspects with Qur'anic values in Islamic boarding schools through digital learning media has not been widely explored.

Therefore, this study has novelty in the application of digital transformation in boarding schools through the STEMQ approach, which has not been widely explored. The main objective of this research is to address the gap related to the low level of scientific literacy in Islamic boarding schools by developing e-module-based learning media integrated with STEMQ. Thus, this research is expected to provide a new contribution to the development of scientific literacy and 21st-century skills in Islamic boarding schools, as well as strengthen the integration of science and religion in education.

The hypotheses in this study are as follows:

- Null Hypothesis (H0): There is no significant improvement in students' science literacy after using the STEMQ-based e-module.

- Alternative Hypothesis (H1): There is a significant improvement in students' science literacy after using the STEMQ-based e-module.

Method

Research design and procedure. This study employed a quasi-experimental design using a one-group pre-test post-test approach. Although this design does not include a control group, rigorous measures were implemented to ensure both internal and external validity. For instance, strict control of confounding variables was maintained during the intervention, and valid, reliable research instruments were used to measure outcomes. Observations were conducted before (pre-test) and after (post-test) the implementation of learning using an e-module based on the STEMQ approach (Science, Technology, Engineering, Mathematics, and Qur'an). The results of the pre-test and post-test served as the primary data to measure the impact of the e-module on improving students' science literacy. Additionally, comprehensive statistical analyses, such as N-Gain tests and ANOVA, were applied to ensure that the observed improvements were genuinely attributable to the intervention provided.

The study was conducted from July to August 2024 in five Islamic senior high schools (Madrasah Aliyah or MA) in Jombang, East Java, Indonesia. MA is equivalent to senior high schools (SMA) in Indonesia, integrating both general and Islamic religious education curricula. The schools were selected through a simple random sampling technique, ensuring that each school had an equal chance of being included. Similarly, the sample of 150 students was randomly selected from the student population without considering rank, gender, or any specific group. This approach enhanced the generalizability of the research findings.

Participant. This study involved 150 students as participants, randomly selected from five Madrasah Aliyah (MA) in Jombang, East Java. MA is equivalent to senior high schools (SMA) in Indonesia, integrating both general and Islamic religious education curricula. The participants comprised 72 male students (48%) and 78 female students (52%), with the majority aged 17 years (66.7%), followed by 18 years (20%), and 16 years (13.3%). Sixty percent of the participants resided in urban areas, while the remaining 40% lived in rural areas. The five schools involved shared relatively similar demographic characteristics, such as close geographical proximity, homogeneous socio-economic backgrounds (primarily middle-income families), and consistent implementation of Islamic-based curricula. The random selection of participants and their even distribution across each school ensured that the research sample was representative and that the findings could be generalized to a broader population.

Research instrument. The instrument used in this study was a science literacy test adapted from the Pan-Canadian Assessment Program (PCAP). The test was modified to align with the learning objectives and cultural context of the participants, including adjustments to the language and examples used in the questions. It covered three main indicators: scientific inquiry, problem-solving, and scientific reasoning (O'Grady and Houme, 2014). The test consisted of 15 essay questions designed to assess students' abilities in each sub-indicator. The instrument's validity was confirmed through a significance test, yielding a p-value of 0.000 (<0.05), while its reliability, measured using Cronbach's Alpha, was 0.936, indicating high consistency.

The science literacy indicators assessed included:

- Scientific Inquiry: Applying the results of scientific investigation, designing and conducting investigations, formulating hypotheses, collecting and analysing data, and interpreting results.
- Problem-Solving: Identifying problems, formulating hypotheses, applying scientific concepts, evaluating solutions, and developing problem-solving strategies.
- Scientific Reasoning: Logical reasoning, using scientific models, evaluating evidence, identifying assumptions, and constructing evidence-based arguments.

Data analysis. Data analysis was conducted by comparing the pre-test and post-test results within the same group of students. Students' scores were calculated based on the percentage of correct answers and classified into science literacy categories: very good (81–100%), good (61–80%), fair (41–60%), poor (21–40%), and very poor (0–20%). To measure the effectiveness of the learning process, N-Gain analysis was used, categorised as high (<g> >0.70), medium (0.31 < g ≤ 0.70), and low (0.0 <g ≤ 0.30). A paired sample t-test was also applied to determine the significance of the differences between the pre-test and post-test results, ensuring the data met the assumptions of normality and homogeneity.

Results and discussion

Results

Analysis of the effect of STEMQ flipbook-based e-module on students' science literacy skills. Based on the research results, the STEMQ Flipbook-based e-module can enhance students' science literacy skills in the learning process conducted in the sample schools. This can be seen from the comparison of Pre-Test and Post-Test results of the research samples, as illustrated in Table 1.

The results of the study presented in Table 1 indicate a significant improvement in students' science literacy skills following the implementation of the Flipbook-based STEMQ e-module. The average science literacy scores of students increased substantially from 35.3–38.9 in the Pre-Test to 80.58–80.62 in the Post-Test across all tested components. This improvement demonstrates that the Flipbook-based e-module is effective in enhancing students' science literacy.

The application of the Flipbook-based STEMQ e-module in physics learning has made students more engaged and facilitated their understanding of the material, particularly in practical lessons. The work steps are explained systematically according to the learning objectives, enabling students to build their

Table 1 Pre-test and post-test scores of research samples (5 schools).

	Pre Test					Post Test				
Component:	**MA_A**	**MA_B**	**MA_C**	**MA_D**	**MA_E**	**MA_A**	**MA_B**	**MA_C**	**MA_D**	**MA_E**
Number of students	30	30	30	30	30	30	30	30	30	30
Highest score	54.7	49.3	45.3	44.0	48.0	98.67	98.67	96.00	98.67	98.67
Lowest score	21.3	24.0	25.3	25.3	25.3	62.67	62.67	62.67	62.67	62.67
Average score	38.9	37.96	36.27	35.7	35.3	80.58	80.58	80.58	80.62	80.62

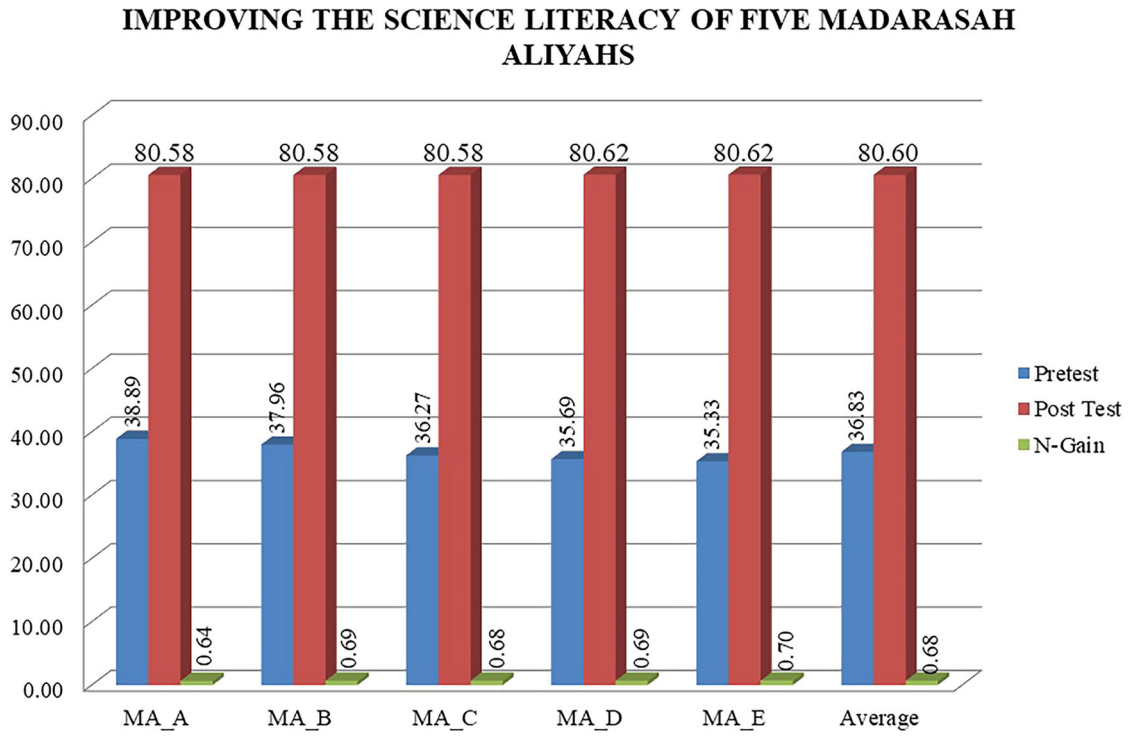


Fig. 1 Data on the Improvement of Science Literacy Results.

knowledge independently. Teachers not only impart knowledge but also facilitate students in critical and systematic thinking, especially concerning optical materials.

The Flipbook features, such as the combination of images, audio, and text, enhance the appeal and comprehension of information for students. The inclusion of videos in the e-module allows students to pause or replay sections if they do not fully understand certain parts. Interactive features such as animations and simulations also help students grasp scientific concepts more effectively than conventional methods.

The integration of STEM principles and Qur'anic values in this e-module strengthens the relevance of the science material, increasing student motivation and engagement. This approach also aids students in connecting scientific concepts with spiritual and practical values, deepening their understanding.

The enhancement of students' science literacy skills through the Flipbook-based STEMQ e-module occurs because students gain a new experience in receiving the material. The average improvement from the Pre-Test to the Post-Test indicates that the research sample students have shown progress, as illustrated in Fig. 1.

Based on Fig. 1, the N-gain indicates that the average improvement of the research sample falls within the moderate criteria. This is influenced by several factors. First, the varying characteristics of students' initial understanding. This variation in understanding affects the extent to which improvement can occur. If students' prior knowledge is already quite good, the increase in scores may be limited as they approach their maximum ability threshold. Second, the design and implementation of the STEMQ Flipbook-based e-module. Although interactive, if the features provided are not engaging or relevant enough, the impact may be diminished. Third, the teaching methods and application of the e-module. If the e-module is not used consistently or applied over a sufficient period, it can affect learning outcomes. Fourth, student engagement is also a critical factor, as motivation and participation in using the e-module influence the results obtained. Overall, the N-gain, which is categorized as moderate (0.68), indicates that the Flipbook-based STEMQ e-module is fairly effective in improving science literacy; however, improvements are still needed, such as enhancing content quality, extending usage duration, and improving the design and integration of the e-module into the learning process.

Table 2 Normality test for pre-test and post-test.

School	Kolmogorov-Smirnov			
	Statistic	Df	Sig	Description
Pre Test MA_A	0.142	30	0.124	Normal
Post Test MA_A	0.136	30	0.166	Normal
Pre Test MA_B	0.140	30	0.136	Normal
Post Test MA_B	0.136	30	0.166	Normal
Pre Test MA_C	0.134	30	0.180	Normal
Post Test MA_C	0.084	30	0.200	Normal
Pre Test MA_D	0.153	30	0.071	Normal
Post Test MA_D	0.135	30	0.174	Normal
Pre Test MA_E	0.116	30	0.200	Normal
Post Test MA_E	0.135	30	0.174	Normal

Furthermore, to identify whether there are significant differences between two or more classes influenced by a single independent variable, an ANOVA test was conducted. This ANOVA test was carried out using IBM SPSS 25 software, referencing a significance level of 0.05. Before performing the ANOVA test, normality and homogeneity tests were first conducted as prerequisites. The results of the normality test, homogeneity test, and ANOVA test obtained from the study are presented. The results of the normality test are shown in Table 2.

Based on the results of the normality test using the Kolmogorov-Smirnov method across five pesantren-based schools, it can be concluded that all Pre-Test and Post-Test data demonstrate a normal distribution. This is indicated by significance values (Sig) that are all greater than 0.05, meaning there is not enough evidence to reject the null hypothesis that the

Table 3 Homogeneity Test.

	Levene Statistic	Df1	Df2	Sig.
Based on mean	1.571	4	145	0.185
Based on median	1.442	4	145	0.223
Based on median and with adjusted df	1.442	4	142.886	0.223
Based on trimmed mean	1.569	4	145	0.186

Table 4 One-Way ANOVA Test.

	Sum of squares	Df	Mean square	F	Sig
Between Groups	44.184	2	22.092	0.038	0.963
Within Groups	103128.764	177	582.648		
Total	103172.948	179			

data is normally distributed. This normal distribution is crucial because the validity of subsequent parametric statistical tests, such as t-tests or ANOVA, relies on the assumption of data normality. With this assumption met, further analysis can be conducted more accurately. Since the data is normally distributed, we proceed with the homogeneity test, the results of which are presented in Table 3.

Based on Table 3, all significance values (Sig.) for the homogeneity test using various approaches (Mean, Median, Median with adjusted degrees of freedom, and Trimmed Mean) are above the significance level of 0.05. This indicates that the variances among groups do not differ significantly, satisfying the assumption of homogeneity. With all significance values greater than 0.05, we can conclude that the assumption of homogeneity of variances has been met. This ensures that the results of the ANOVA test to be conducted will not be influenced by differences in variances among groups. Subsequently, a one-way ANOVA test is presented in Table 4.

A one-way ANOVA test is used to determine whether there are significant differences between the means of three or more groups. In this study, a one-way ANOVA was conducted to evaluate the differences among groups based on the tested independent variables. Based on Table 4, the obtained Sig. value is 0.963, which is much larger than the significance level of 0.05, so we do not reject the null hypothesis. This indicates that there are no significant differences in the means among the groups tested. The very small F value (0.038) suggests that the variation between groups is minimal compared to the variation within groups, supporting the result that there are no significant differences. Sig $0.963 > 0.05$, meaning there are no significant differences among the groups. An additional test was also conducted to determine the relationships between each sample group in the study, specifically a Post Hoc Test (Bonferroni). The results of the Post Hoc Test are presented in Table 5.

Based on Table 5, the results of the Bonferroni Post Hoc Test show the comparison between each pair of groups based on Mean Difference (I-J), Standard Error, and Significance (Sig). In these results, all p values (Sig.) for the comparisons between the pairs of groups are 1.000, which is much greater than the significance level of 0.05. This indicates that there are no significant differences in the averages among all pairs of groups tested.

Analysis of students' science literacy skills. The next step is to measure students' science literacy skills after the implementation of the STEMQ-based flipbook e-module. The post-test questions are categorized according to the science literacy indicators being assessed, namely scientific inquiry, problem solving, and scientific reasoning. The percentage scores are calculated for each indicator based on students' answers. Afterward, the average percentage of correct scores from all students is analyzed using five achievement categories: very good, good, fair, poor, and very poor. These categories are based on Ridwan's assessment standards. The results of the science literacy skills percentage based on the science literacy indicators are presented in Table 6 and Fig. 2.

Based on Fig. 2, it is evident that overall, students' science literacy abilities are classified as very good in Indicator 1 and good in Indicators 2 and 3. This indicates that students possess a strong understanding of basic science concepts; however, there is a need for improvement in problem-solving skills and scientific reasoning. Indicator 1 shows that students' understanding of basic science concepts is already very good. The high consistency of scores across schools indicates the effectiveness of teaching in this indicator. Indicator 2 indicates that students' ability to apply science concepts to solve problems is fairly strong, but there are some variations among schools. MA_B has a lower score, suggesting a need for a more intensive approach in teaching problem-solving aspects. Indicator 3 demonstrates that although students' scientific reasoning is quite good, the inconsistent results indicate that students require more practice or different approaches to develop this skill. These findings suggest the need for a greater emphasis on developing problem-solving abilities and scientific reasoning in the science curriculum at madrasahs. A more integrated learning approach and the use of innovative teaching methods, such as the STEMQ approach, could help enhance students' abilities in both aspects.

Discussion

Analysis of the effect of STEMQ flipbook-based e-module on students' science literacy skills. Based on the research findings, the STEMQ Flipbook-based e-module has proven effective in enhancing students' scientific literacy across five schools sampled in the study. Data presented in Table 1 indicate a significant increase in scientific literacy scores from the pre-test to the post-test in all schools. The average pre-test scores ranged from 35.3 to 38.9, while the average post-test scores increased to 80.58 to 80.62. This improvement demonstrates that the e-module successfully facilitated students' understanding of light-related topics, particularly in physics education. The e-module provided a more interactive and in-depth learning experience, thereby enhancing students' comprehension of scientific concepts. A meta-analysis revealed that e-modules are significantly more effective than traditional methods, with an effect size of $d = 18.45$, indicating a substantial improvement in learning outcomes (Fadillah et al. 2024). These findings align with the study by Linda et al. (2020), which showed an enhancement in students' self-directed learning processes after using e-modules. Additionally, research by Fatimah et al. (2024) suggests that online module-based learning can provide STEM experiences that foster curiosity-driven classroom dynamics and knowledge acquisition, thereby improving scientific literacy, critical thinking skills, and correcting common scientific misconceptions.

The effectiveness of the STEMQ Flipbook-based e-module is influenced by several factors. Firstly, interactive features such as animations, simulations, and videos within the e-module allow students to explore scientific concepts in a more engaging and contextual manner. E-modules designed with interactive elements, such as quizzes and simulations, encourage critical thinking and student engagement, thereby enhancing understanding of physics concepts (Restiani et al. 2024). Replayable

Table 5 Post hoc test.

(I) School	(J) School	Mean difference (I-J)	Std. Error	Sig.	95% Confidence interval	
					Lower bound	Upper bound
MA_A	MA_B	0.00000	2.93563	1.000	−8.3684	8.3684
	MA_C	0.00000	2.93563	1.000	−8.3684	8.3684
	MA_D	−0.04433	2.93563	1.000	−8.4127	8.3241
	MA_E	−0.04433	2.93563	1.000	−8.4127	8.3241
MA_B	MA_A	0.00000	2.93563	1.000	−8.3684	8.3684
	MA_C	0.00000	2.93563	1.000	−8.3684	8.3684
	MA_D	−0.04433	2.93563	1.000	−8.4127	8.3241
	MA_E	−0.04433	2.93563	1.000	−8.4127	8.3241
MA_C	MA_A	0.00000	2.93563	1.000	−8.3684	8.3684
	MA_B	0.00000	2.93563	1.000	−8.3684	8.3684
	MA_D	−0.04433	2.93563	1.000	−8.4127	8.3241
	MA_E	−0.04433	2.93563	1.000	−8.4127	8.3241
MA_D	MA_A	0.04433	2.93563	1.000	−8.3241	8.4127
	MA_B	0.04433	2.93563	1.000	−8.3241	8.4127
	MA_C	0.04433	2.93563	1.000	−8.3241	8.4127
	MA_E	0.00000	2.93563	1.000	−8.3684	8.3684
MA_E	MA_A	0.04433	2.93563	1.000	−8.3241	8.4127
	MA_B	0.04433	2.93563	1.000	−8.3241	8.4127
	MA_C	0.04433	2.93563	1.000	−8.3241	8.4127
	MA_D	0.00000	2.93563	1.000	−8.3684	8.3684

Table 6 Percentage of Students' Science Literacy Skills (Post-test) (%).

	School					Average	Category
	MA_A	MA_B	MA_C	MA_D	MA_E		
Indicator 1	83.7	80.5	81.3	83.7	81.3	82.1	Very good
Indicator 2	80.5	77.5	81.3	80.7	81.1	80.2	Good
Indicator 3	77.5	83.7	79.1	77.5	79.9	79.5	Good

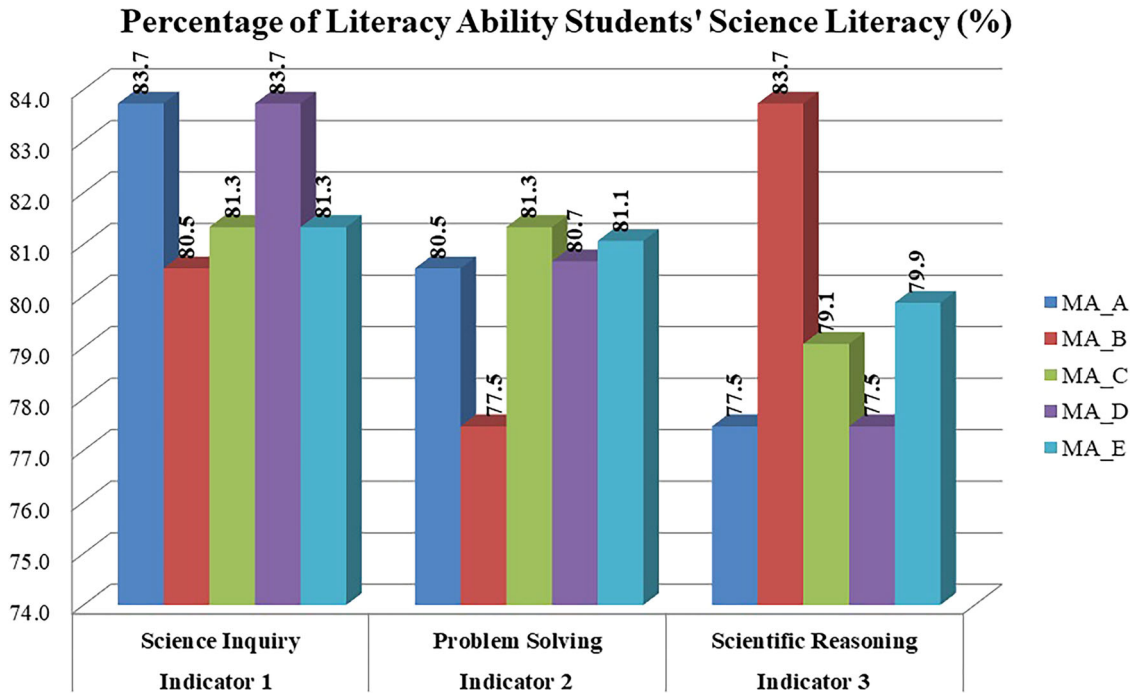


Fig. 2 Percentage of Literacy Ability Students' Science Literacy.

videos provide students with opportunities to deepen their understanding of challenging topics (Genereux, 2017). Recent studies indicate that the use of technology, such as digital simulations and virtual laboratory tools, can significantly improve students' comprehension (Kurniawan et al. 2025). Research by Nareswari et al. (2024) demonstrates that Flipbooks equipped with pre-tests, instructional videos, post-tests, and games support students in solving problems creatively, independently, and logically, while also introducing local wisdom. The use of technology in education can enhance literacy achievement and motivation when educators select technologies aligned with learning objectives and curriculum standards (Daggett, 2018). The STEM approach through technological media can also improve students' technological literacy (Utami and Wilujeng, 2020) and provide opportunities for students to apply knowledge and solve real-world problems through engineering processes that foster mastery and creativity (Anjarsari et al. 2020).

Secondly, the integration of STEM principles and Qur'anic values in the e-module makes the learning process more relevant and meaningful for students. This relevance increases students' motivation and helps them connect scientific concepts with Qur'anic verses. Integrating STEM topics into subjects is an effective way to deliver knowledge as it combines creativity, motivation, and curiosity (Salama et al. 2019). This is consistent with the findings of Ilafi et al. (2024), which show that STEM-PjBL-based science e-books can enhance students' learning motivation and creative thinking skills. STEAM learning is effective in supporting deep thinking and increasing students' interest in science and technology (Vachhiyat and Tandel., 2025; Gracia et al. 2024); Huda et al. 2024).

Despite the observed improvements, the enhancement in scientific literacy remains in the moderate category (N-gain 0.68). This is influenced by several factors, such as differences in students' initial understanding, suboptimal e-module design, and limited duration of e-module use. Students' initial characteristics, including prior knowledge, learning styles, and technological literacy, can affect their engagement and understanding of the e-module. For instance, students from environments with limited access to technology require more time to adapt to Flipbook-based e-modules compared to those already familiar with digital devices. Additionally, demographic characteristics such as age and gender influence students' learning styles. Younger students are more attracted to visual and interactive elements in e-modules, while older students require more in-depth textual explanations. Research indicates that students' learning styles (visual, auditory, kinesthetic) can be influenced by demographic factors such as cultural background or learning environment.

Students' technological literacy, which may be influenced by demographic factors such as geographical location or socio-economic status, also plays a role in the effectiveness of e-modules. Students from urban areas with good internet access adapt more quickly to e-modules compared to those from rural areas with limited technological infrastructure. Demographic characteristics such as gender or cultural background can also affect students' motivation and engagement in using e-modules (Teplá and Distler, 2025). For example, studies show that female students are more interested in structured and contextual learning approaches, such as the integration of Qur'anic values in STEMQ e-modules.

Statistical tests indicate no significant differences between schools, suggesting that the e-module is consistently effective across various contexts. However, demographic characteristics such as differences in school resources, students' socioeconomic backgrounds, or educational policies in each school may influence the implementation of e-modules. For instance, schools with more advanced technological facilities can optimise the use of e-modules better than those with limited resources. This aligns with the study by Vanthournout et al. (2012), which states that students' learning approaches, whether deep or surface-level, affect their engagement with e-modules. Students with a deep approach tend to demonstrate better understanding and retention of material. Research by Gunsri et al. (2023) also shows that e-modules present reading materials in an engaging manner and support diverse learning styles, thereby facilitating comprehension for students with varying abilities and skills. Furthermore, well-designed e-modules can reduce cognitive load and enhance students' understanding (Guo et al. 2024).

In conclusion, the STEMQ Flipbook-based e-module has proven effective in enhancing students' scientific literacy. However, to optimise learning outcomes, improvements in content design, duration of use, and alignment with students' demographic characteristics are necessary. By considering these factors, e-modules can become more effective in supporting inclusive and meaningful science education for all students.

Analysis of students' scientific literacy skills. Following the implementation of the STEMQ Flipbook-based e-module, students' scientific literacy skills were assessed based on three indicators: scientific inquiry (Indicator 1), problem-solving (Indicator 2), and scientific reasoning (Indicator 3). The results revealed that students' ability to understand basic scientific concepts (Indicator 1) was in the excellent category, with an average score of 82.1%. Meanwhile, problem-solving skills (Indicator 2) and scientific reasoning (Indicator 3) were in the good category, with average scores of 80.2% and 79.5%, respectively. This indicates that students possess a strong understanding of fundamental scientific concepts and can effectively apply them in investigations. The STEMQ Flipbook-based e-module integrates five key aspects: Science, Technology, Engineering, Mathematics, and the Qur'an.

- Science: Students explore the properties of light, such as reflection, refraction, and dispersion, through experiments using mirrors and prisms.
- Technology: Students utilise technology by applying principles of light to create simple optical devices, such as periscopes, and understand the workings of cameras.
- Engineering: Students design energy-efficient LED lamps, considering light intensity and dispersion angles.
- Mathematics: Students calculate reflection and refraction angles using Snell's Law.
- Qur'an: Students relate light phenomena to Qur'anic verses, such as QS. An-Nur (24:35), which describes light as a symbol of guidance and knowledge.

The integration of these five aspects is illustrated in the STEMQ Diagram (Fig. 3), which demonstrates how each aspect interconnects and supports the enhancement of students' scientific literacy. The application of the STEM-based module in learning activities yielded significant results, with satisfactory improvements and strong effect sizes (Utami et al. 2020).

This study highlights the effectiveness of the STEMQ Flipbook-based e-module in fostering scientific literacy, particularly in strengthening students' understanding of scientific concepts and their ability to apply them in real-world contexts. The integration of religious values through Qur'anic references further enriches the learning experience, aligning scientific knowledge with spiritual insights.

Figure 4 illustrates an example of a scientific literacy question, focusing on the Science Investigation indicator. This indicator includes the sub-indicator of Applying the Results of Scientific Investigations, as well as the broader indicator of Investigating the Process of Image Reflection in Two Mirrors at a Specific Angle.

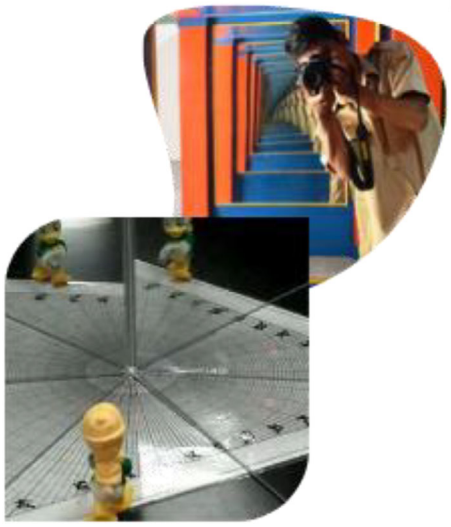
Fig. 3 STEMQ flipbook-based e-module (Link: https://heyzine.com/flip-book/a5727a7359.html).

Based on the results presented in Fig. 4, it is evident that the high consistency of scores in Indicator 1 across all schools demonstrates that the teaching of basic science concepts is already effective. However, in Indicator 2, there is variation among schools, with MA_B recording a lower score (77.5%). This indicates the need for a more intensive approach in teaching problem-solving aspects. In Indicator 3, although the average score is relatively good (79.5%), the inconsistent results across schools suggest that students require more practice or alternative approaches to develop scientific reasoning skills.

These findings highlight that the science curriculum in madrasahs needs to place greater emphasis on the development of problem-solving and scientific reasoning skills. The adoption of more innovative and integrated teaching methods, such as the STEMQ approach, could serve as an effective strategy to enhance students' abilities in these areas. Appropriate teacher training, as well as the development and monitoring of projects aligned with the principles of institutional models and policies outlined in the Educational Development Plan (RPP), are crucial in supporting STEM education (Mesa et al. 2022).

Overall, this study demonstrates that the STEMQ-based Flipbook e-module is effective in improving students' scientific literacy. However, further improvements are needed in terms of e-module design, teaching methods, and a stronger focus on specific aspects of scientific literacy.

The Mystery of the Hallway of a Thousand Shadows



In a ride called Lorong Seribu Shadow, visitors can experience a unique and mysterious sensation. Once you enter this hallway, you will be faced with a mirror that reflects an unusually large number of your own shadows. The question is, why do you see so many shadows?

Mirrors are smooth surfaces that create reflections. The history of mirrors dates back thousands of years, from shiny pieces of obsidian stone, to the metal-coated glass mirrors we use today. In this ride, flat mirrors are used as reflectors. The shadow formed on a flat mirror is virtual, upright, and behind the mirror. The distance of the shadow to the mirror is equal to the distance of the object to the mirror, and the height of the shadow is equal to the height of the object.

The magic of the Hall of a Thousand Shadows happens when two flat mirrors are placed facing each other on the left and right sides of the hallway wall. When you stand between them, these mirrors will reflect your image back and forth repeatedly, making it appear as if the shadows are infinite. This is the basic principle of flat mirrors that produce multiple shadows when faced.

The number of shadows you see depends not only on the mirrors facing each other, but also on the angle formed between the two mirrors. For example, if the angle between the two mirrors is 120 degrees, you will see two shadows. If the angle is reduced to 90 degrees, the shadows will increase to three, and if the angle is only 30 degrees, the number of shadows will reach eleven. Here are the results of the experiment:

Experiment	Angle (°)	Number of Shadows
1	120	2
2	90	3
3	60	5
4	45	7
5	30	11

Question

1. From the reading above Determine the experimental steps and experimental variables used to determine the number of shadows formed with a predetermined angle based on the table above!

   _____

2. Based on the reading above, determine how to determine the amount of shadow formation on two flat mirrors, as well as how to obtain a large number of shadows on the two flat mirrors!

   _____

3. Based on the results of the investigation and problem solving carried out through the reading above, write down the conclusions that you can get related to the formation of shadows on two flat mirrors!

   _____

Fig. 4 Science literacy questions.

Integration of e-modules in learning. The STEMQ-based Flipbook e-moduleffectively integrates STEM principles with Quranic values, fostering independent learning through interactive multimedia elements such as images, audio, text, and videos. This approach is grounded in constructivist theory, which emphasises experiential learning and active student engagement with the material. The design of the e-module enables in-depth exploration of scientific concepts, such as light, through features like replayable videos and systematic presentations, thereby facilitating students' understanding of complex topics.

The effectiveness of this e-module has been demonstrated in enhancing students' motivation and engagement in science learning, as evidenced by research conducted by Sari et al. (2024). Furthermore, the module promotes better interaction between students and learning materials, ultimately deepening their conceptual understanding. Additional studies by Hasanah and Sari (2024) and Yusmar et al. (2024) confirm the validity and practicality of the e-module, with validity scores reaching 95%, indicating its efficacy in supporting self-directed learning.

The constructivist framework underpinning the e-module encourages students to actively engage in the learning process, aligning with the principle that knowledge is constructed through direct interaction with the material (Syukri et al. 2024). The user-friendly design and integration of multimedia elements make the learning experience more accessible and engaging, catering to diverse learning styles such as visual, auditory, and kinesthetic (Fathurroziq and Astutik, 2024). Thus, the STEMQ-based Flipbook e-module not only facilitates the understanding of scientific concepts but also strengthens the connection between science and spiritual values, creating a holistic and meaningful learning experience.

The implementation of the e-module in the classroom actively involves students, with teachers assuming the role of facilitators or supporters in the learning process, guiding discussions and providing assistance during practical activities (Yulianti and Purwati, 2024). Students actively participate in these activities, which enhances their engagement and understanding of the material. Interactive features in the e-module, such as animations and simulations, allow students to observe real-world applications of the concepts they are learning. This is particularly important in science education, where visualisation can help explain complex phenomena. After learning with the e-module, students undertake practical activities based on provided worksheets (https://tinyurl.com/mtew9ad8). These activities are designed to reinforce their understanding and apply the acquired knowledge in practical contexts, which is central to the approach (Darmansyah et al. 2024). Thus, the implementation of the Flipbook-based e-module not only enhances students' understanding but also fosters critical thinking and collaborative skills in science learning.

The STEMQ Flipbook-based e-module initiative significantly improves students' scientific literacy by integrating Quranic values into STEM. This approach not only deepens students' understanding of scientific concepts but also builds a connection between science and spirituality, making learning more holistic and meaningful. The e-module incorporates Quranic verses that align with scientific concepts, such as light, thereby enriching the learning experience (SAL et al. 2024). This integration encourages students to view science as a discipline that complements their spiritual beliefs, promoting a more comprehensive understanding of both domains (Siron, 2024).

The interactive nature of the Flipbook e-module has been shown to enhance students' motivation and engagement in learning (Fathurroziq and Astutik, 2024). The practical application of STEM concepts, linked to religious teachings, helps students connect scientific knowledge with their daily lives (Masykur et al. 2024). Research indicates that the e-module is effective, with high validity and practicality scores from educators and students (SAL et al. 2024). This approach not only improves conceptual understanding but also develops critical thinking by encouraging students to connect science with broader contexts, including moral and ethical considerations (Juwairiyah and Fanani, 2025).

Based on the above discussion, it can be concluded that the impact of STEMQ on students' scientific literacy is influenced by various factors, including e-module design, the integration of Quranic values, students' initial characteristics, the role of teachers, duration of use, and the learning environment. To optimise the positive impact of this approach, improvements in content design, teacher training, and the continuous integration of e-modules into the curriculum are necessary. Future research could focus on developing more innovative learning methods to enhance students' problem-solving and scientific reasoning skills, as well as exploring the impact of integrating spiritual values into science education in greater depth.

Conclusion

Fundamental finding. Based on the results of this study, it can be concluded that the application of Flipbook-based STEMQ e-modules has a significant positive impact on improving students' science literacy skills in the five schools studied. Data shows that students' science literacy scores improved from pre-test to post-test, with a significant increase in the average post-test scores across all schools. This e-module, with interactive features such as animations, simulations, and videos, has proven effective in facilitating a deeper and more engaging understanding of science concepts.

Implication. However, the analysis results also reveal variations in student improvement, with the science inquiry indicator showing very good achievement, while the problem-solving and scientific reasoning indicators still require further attention. Statistical tests indicate no significant differences between school groups, suggesting consistent effectiveness of this e-module across the sample.

Limitation. Although this study demonstrates that the Flipbook-based STEMQ e-module has a positive impact on enhancing science literacy, several limitations need to be noted. This research employed a broad experimental approach but did not delve into qualitative aspects such as students' responses with different learning styles to this module. This leads to a lack of deep understanding of how factors like learning preferences influence students' score improvements. Furthermore, while the e-module has been generally effective, this study did not explore students' learning style differences in detail, nor did it consider external factors such as socioeconomic background, parental support, and teacher quality.

Future research. Further research is needed with a larger sample size and a longer duration to generalize the findings of this study. External factors such as students' socioeconomic background, parental support, and teacher quality should also be considered in future studies. The e-module used still needs further development to accommodate various learning styles and meet more specific learning needs. More in-depth evaluations are also necessary to measure the impact of the e-module on other aspects of science learning, such as student attitudes and critical thinking skills.

Data availability

No datasets were generated or analysed during the current study.

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Author contributions

Suci Prihatiningtyas was responsible for drafting the original manuscript. [Noly Shofiyah] conceptualized the study and led the review and editing process. [Sitti Rahma Yunus] and [Ino Angga Putra] conducted the literature search and data analysis, with [Ino Angga Putra] also assisting in providing resources. [Iin Baroroh Ma'arif] contributed essential resources for the research. All authors have read and approved the final version of the manuscript.

Competing interests

The authors declare no competing interests.

Ethical approval

This study was approved by the Research Ethics Committee of KH. A. Wahab Hasbullah University (Approval Number: 089/LPPM-UNWAHA/S.Ket/VI/2024). The study protocol, including the purpose, methodology, participant recruitment, module content, and the scientific literacy test, was submitted to the committee and formally approved on June 4, 2024, following a full review. All research activities followed the ethical principles outlined in the Declaration of Helsinki.

Informed consent

Written informed consent was obtained from all participants on June 27, 2024, prior to their participation in the pre-test and post-test conducted during the research period in July-August 2024. Additionally, prior institutional consent was obtained from the school principal on June 24, 2024, in accordance with the institution's policy for minimal-risk educational research. All participants were clearly informed about the purpose and process of the study, including the use of pre-test and post-test data to evaluate the effectiveness of the STEM Qur'an Flipbook-based e-module. Participants were assured of their anonymity and confidentiality, and they were informed that the data collected would be used solely for academic research purposes. Furthermore, participants were assured that the study would not cause any harm or adverse effects during or after the research process.

Additional information

Correspondence and requests for materials should be addressed to Suci Prihatiningtyas or Noly Shofiyah.