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E-Module Design Based on STEM and RME for Student Numeracy Development in Senior High Schools: Insights from a Needs Analysis

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Abstract. This study aims to analyze the needs of students and teachers in developing e-modules for mathematics learning based on the STEM (Science, Technology, Engineering, and Mathematics) and RME (Realistic Mathematics Education) approaches. This study used a descriptive approach with 203 students and 6 mathematics teachers from several high schools in Bekasi City as subjects. Data were collected through four types of instruments, namely numeracy tests, student needs questionnaires, teacher needs questionnaires, and semi-structured interviews. Data analysis was conducted using the Miles & Huberman model, which includes the stages of data collection, data reduction, data presentation, and conclusion drawing. The results of the analysis showed that the students had difficulties in understanding the material, performing calculation operations, and solving mathematical problems. The students also show low self-efficacy and require contextual, interesting, and interactive teaching materials. The students' preferences for the appearance of the e-module include the use of colors that are not excessive, consistent fonts, simple navigation, and communicative language. On the other hand, teachers show a limited understanding of the STEM-RME approach and have not fully integrated the approach into learning. The teachers express the need for learning strategies and media that can improve students' numeracy and self-efficacy and emphasize the importance of training in the use of digital media. These findings provide an important basis for designing e-modules that meet the requirements and characteristics of users, namely students and teachers, to support the effectiveness of mathematics learning.

Keywords: STEM; RME; e-module; numeracy; needs analysis

INTRODUCTION

Mathematics education in Indonesia faces major challenges in meeting the demands of 21st-century education, especially in strengthening students' numeracy skills (Deda et al., 2023). These challenges include the gap between curriculum expectations and classroom practice, limited teacher capacity in implementing context-based mathematics learning, and low student performance in international assessments such as PISA and TIMSS. These conditions indicate an urgent need to reform the way mathematics is taught and learnt in schools to better prepare students for real-world problem solving.

Numeracy is an important skill that affects students' success in everyday life and the world of work. It reflects the extent to which students can understand, interpret, and use mathematical concepts in relevant contexts (Aunio et al., 2016; Cohrssen & Niklas, 2019; Tout & Gal, 2015).

Various curriculum reforms have been carried out in Indonesia, but the achievement of mathematics learning outcomes at the secondary school level is still not optimal. Based on the Programme for International Student Assessment (PISA) results, Indonesian students' mathematics literacy and numeracy are consistently below the international average, indicating the need for substantial and sustained interventions (OECD, 2023). In addition, the approach to mathematics learning in Indonesia is still dominated by conventional methods that are abstract and theoretical, with limitations in linking concepts to real situations. This has an impact on students' low numeracy (Hidayah et al., 2021; Megawati & Sutarto, 2021; Miralda et al., 2022).

Despite these challenges, the integration of technology into mathematics learning has shown great potential in increasing student participation and understanding. The utilization of digital media, particularly electronic modules (e-modules), provides an opportunity to make learning more interactive, flexible, and up-to-date (Geiger, 2015; Miller, 2018). E-modules not only allow wider access to learning but also support the presentation of more contextual and multimodal materials through the integration of visual, audio,

and interactive elements (Hadiyanti et al., 2021; Kementerian Pendidikan dan Kebudayaan, 2017; Najuah et al., 2020).

In line with these developments, the Science, Technology, Engineering, and Mathematics (STEM) and Realistic Mathematics Education (RME) approaches are two complementary approaches in supporting meaningful mathematics learning. The STEM approach emphasized interdisciplinary integration and the application of science in real life, while RME emphasized the mathematization process through contexts that are relevant and meaningful to students (Gravemeijer & Terwel, 2000; Khotimah et al., 2021; Kurt & Benzer, 2020). The integration of STEM-RME in learning allows students to develop their critical thinking, problem-solving, and connection skills between mathematics concepts and daily life.

In this context, the development of e-module design based on STEM and RME is seen as a strategic alternative to improve the numeracy of secondary school students. This approach allows the presentation of mathematical concepts in a context-rich and applicable digital environment, while fostering student motivation and engagement in the learning process. However, before the module is developed, an initial study in the form of needs analysis is required to ensure that the e-module developed meets the real needs of students and teachers in the field.

The needs analysis is a crucial stage in the learning media development process, as it provides an empirical basis for identifying the gap between actual conditions and ideal expectations. Through the identification of students' needs for numeracy learning as well as teachers' preferences for effective teaching media, the e-module development process can be more targeted, pedagogically relevant, and have an impact on improving students' numeracy competence.

Thus, this study aims to conduct a needs analysis to develop a mathematics e-module based on the STEM-RME approach that can support the improvement of high school students' numeracy. The results of this study are expected to be a strong initial foothold in designing learning media that are innovative, contextual, and adaptive to the challenges of mathematics education in Indonesia.

METHODS

This research is a descriptive study that aims to analyze the needs of students and teachers as a basis for developing mathematics e-modules based on the STEM-RME approach to improve numeracy of senior high school students. This research was conducted in the first stages of the ADDIE (Analyze, Design, Develop, Implement, Evaluate) development model, namely the needs analysis stage (Analyze). The research subjects consisted of 203 students and 6 high school mathematics teachers in Bekasi City, who were selected randomly. This technique was chosen to obtain more representative data and reduce potential bias in sample selection.

Data were collected using four types of instruments: a numeracy test, a student needs questionnaire, a teacher needs questionnaire, and semi-structured interviews. The numeracy test was used to measure students' numeracy in an applied mathematics context. The student needs questionnaire aims to identify their perceptions and expectations of mathematics learning, as well as digital learning media that suit their learning needs. Meanwhile, the teacher needs questionnaire was used to gather information about the challenges faced by teachers in teaching numeracy, the need for interactive learning media, and teachers' views on the importance of STEM and RME approaches in the mathematics learning process. In addition, interviews were conducted with selected students and teachers to deepen the understanding of the quantitative data obtained from the three previous instruments. Tests and questionnaires were administered to all students and teacher respondents, while interviews were only conducted with a subset of participants selected based on preliminary results and considerations of data representativeness.

The data analysis used followed the Miles & Huberman (1994) model, which consists of: data collection, data reduction, data display, and verification. Analysis of the numeracy test results, and questionnaire was carried out by calculating the average score on each indicator, then converted into a percentage using the following formula.

$$x = \frac{Score}{Ideal\ Score} \times 100\%$$

Furthermore, the percentage results were classified into the categories listed (Herlina et al., 2023) in Table 1 below.

Table 1. Numerical Achievement Categories and Levels of Need by Percentage

Percentage	Category
$80 < x \leq 100$	High
$70 < x \leq 80$	Medium
$0 \leq x \leq 70$	Low

RESULTS AND DISCUSSION

This section presents the results of the analysis based on data obtained from numeracy tests, student and teacher questionnaires, and interviews conducted with a selected number of respondents. The first result presented relates to the current condition of students' numeracy, particularly in solving problems that represent numeracy indicators. In this study, students were given five numeracy problems, each designed to measure ability on a different indicator. Data from students' work on these problems were analyzed to identify the level of proficiency as well as the difficulties faced by students. A summary of students' abilities in solving the five problems is presented in the following table.

Based on the data in Table 2, it can be concluded that the students' mastery of numeracy is generally in the low category in all indicators measured. The first indicator, namely the ability to use various kinds of numbers related to basic mathematics in solving daily life problems, obtained the highest average score (mean = 2.33) with a mastery percentage of 58.25%. However, this score is still in the low category. The second indicator, which measures the use of mathematical symbols in real-life contexts, showed a mean score of 1.40 with a percentage of 34.98%. The third and fourth indicators, relating to the ability to analyze information in the form of graphs and diagrams, had mean scores of 1.48 and 1.19, respectively, with percentages of 37.07% and 29.80%. The lowest was the fifth indicator, which is interpreting the results of the analysis for decision making, with an average of 1.07 and a percentage of only 26.85%. These findings indicate that the students still experience substantial difficulties in higher-level numeracy, such as data interpretation such as data interpretation and quantitative information-based decision-making.

These results are in line with the findings of OECD (2023) in the PISA report, which shows that many Indonesian students are still at a low level in numeracy competence, especially in applying mathematics in real-world contexts. This points to the need to design contextualized and meaningful learning, such as STEM and RME approaches that emphasize the connection between mathematical concepts and everyday life (Bybee, 2013; Gravemeijer & Doorman, 1999). In constructivist theory, meaningful learning occurs when students are able to connect new knowledge with real experiences or prior knowledge (Roth, 2012). Therefore, the STEM-RME approach is very relevant as it encourages students to actively build understanding through explorative activities, problem solving, and contextual reflection. Thus, these results provide a strong basis for designing mathematics learning e-modules that not only pay attention to the conceptual delivery of materials but also build strong connections between real-life contexts and students' numeracy, thus strengthening active, relevant, and meaningful learning processes.

The second result presented is the findings from the students' needs analysis questionnaire on STEM-RME-based mathematics e-modules. The questionnaire was designed to explore students' perceptions related to their ability to understand mathematics, difficulties faced in the learning process, learning needs, learning styles, and

Table 2. Number of Students Based on Grade Scores on the Numeracy Test

Question Number	Numeracy Indicator	Mean	Percentage	Category
1	Using a wide variety of numbers related to basic mathematics in solving problems in a wide variety of daily life contexts	2.33	58.25	Low
2	Using a wide variety of symbols related to basic mathematics in solving problems in a wide variety of daily life contexts	1.40	34.98	Low
3	Analysing information displayed in the form of graphs	1.48	37.07	Low
4	Analysing information displayed in the form of diagrams	1.19	29.80	Low
5	Interpreting the results of analysis to make decisions	1.07	26.85	Low
	Ideal Score	**4.00**		

Table 3. Percentage of the Questionnaire Results on Student Needs Analysis

Dimension	Indicator	Mean	Percentage	Category
Maths learning difficulties	Students' perceptions of their ability to understand mathematical material	3.08	61.63	Low
	Students' perceptions of their ability to perform mathematical arithmetic operations	3.22	64.33	Low
	Students' perceptions of their ability to solve mathematical problems	3.09	61.87	Low
Motivational and psychological factors	Having a desire to learn without external coercion	3.76	75.27	Medium
	Having a positive view of mathematics	3.43	68.52	Low
Learning resources	Having teaching materials/other learning resources to learn mathematics	2.93	59.69	Low
	Having access to the internet	4.21	82.92	High
	Identifying the display of teaching materials/learning resources desired by students	4.15	84.11	High
Learning facilities and technology	Having technological equipment, such as smartphones/tablets that support learning activities	4.34	86.75	High
	Being able to use smartphones/tablets to learn mathematics	4.37	87.49	High
	Ideal Score	**5.00**		

preferences for digital learning media. The detailed results of this questionnaire will provide a more comprehensive picture of students' needs in the numeracy learning process using innovative and contextualized electronic media.

Table 3 shows that the students still experience difficulties in understanding mathematical materials (mean 3.08), performing arithmetic operations (mean 3.22), and solving mathematical problems (mean 3.09), all of which fall into the low category. This reflects the challenges in numeracy learning that need to be addressed. In terms of motivation and psychology, students have a fairly strong desire to learn without external pressure (mean 3.76; medium category) but still show a less positive view of mathematics (mean 3.43; low category). This indicates an internal potential that can be utilized further through interesting and contextualized learning approaches. Furthermore, students' readiness in terms of learning resources and technology facilities is very high, as seen from the mean score of internet access (4.15), identification of teaching material display (4.21), and ownership and ability to use digital devices (4.34-4.35), all of which are in the high category. These findings indicate that the development of digital-based learning media such as e-modules is highly relevant. According to Clarke et al. (2016) the use of multimedia in learning can improve understanding if designed by cognitive principles. In addition, effective utilization of technology can also accommodate different learning styles and increase student engagement (Prensky, 2010), so an interactive e-module based on the right approach is a potential solution in supporting student numeracy achievement.

The indicator ‘Identifying the appearance of teaching materials/learning resources desired by students’ provides an overview of students' preferences for the form and visual features of learning media that they consider attractive and easy to understand. The questionnaire results show that the students expect an interactive e-module display, minimalist colors, consistent fonts, and to be equipped with visual illustrations or animations that support the explanation of concepts. In addition, in interviews, students also

Table 4. Percentage of the Questionnaire Results on Teacher Needs Analysis

Dimension	Indicator	Mean	Percentage	Category
The need for teaching materials	Providing contextual teaching materials	2.67	53.33	Low
	Providing teaching materials that support strengthening numeracy	2.33	46.70	Low
Mastery of the STEM-RME approach	Understanding the STEM approach	3.00	60.00	Low
	Understanding the RME approach	4.67	93.30	High
	Having experience integrating the STEM-RME approach	1.00	20.00	Low
Problems in student numeracy	Recognizing students' difficulties in numeracy	4.33	86.67	High
	Requiring strategies/media to improve students' numeracy skills	4.42	88.33	High
Student self-efficacy	Recognizing students' low confidence in learning mathematics	4.50	90.00	High
	Requiring teaching materials that can increase students' self-efficacy	4.33	86.67	High
Technology support	Providing ICT facilities that support learning	5.00	100.00	High
	Being able to use digital media in learning	3.33	63.30	Low
	Ideal Score	5.00		

wanted simple navigation, the use of communicative and less formal language, as well as interactive practice questions and immediate feedback to increase engagement and understanding. These preferences align with the principle of learner-centered design, which emphasized the importance of tailoring learning design to students' needs, characteristics, and interests to make the learning process more effective and meaningful (Branch, 2009).

The findings from students provide an initial picture of end-user preferences. However, to design a truly effective and applicable e-module, input from teachers as the main facilitator in the learning process is also required. The following is a description of the results of the teacher needs questionnaire.

Based on the results of the teachers' needs analysis shown in Table 4, it can be seen that the dimensions of Students' numeracy problems and Students' self-efficacy obtained the highest mean scores, 4.42 and 4.50, respectively, with the category ‘High.’ This shows that teachers are well aware of numeracy problems and students' low self-confidence in learning mathematics. In addition, teachers also really need learning strategies and media that can improve students' numeracy and self-efficacy. This need is in line with Bandura (1997) opinion, which emphasized the importance of self-efficacy in the achievement of students' academic performance, as well as the importance of teacher support in creating an empowering learning environment.

On the other hand, the dimension of mastery of the STEM-RME approach by teachers is still in the ‘low’ category. The majority of teachers only understand the Realistic Mathematics Education (RME) approach, while understanding of the Science, Technology, Engineering, and Mathematics (STEM) approach is still limited.

This shows that teachers' experience in integrating the two approaches into the learning process is inadequate. Given the importance of implementing this approach in improving the quality of mathematics learning and the low score on the STEM-RME integration indicator (mean = 1.00), a training or professional development programme specifically focused on implementing

the STEM-RME approach is required.

Wijaya et al. (2016) explained that the RME approach is effective in developing students' conceptual understanding and mathematical thinking skills, especially when combined with an applicable STEM context. Roberts & Cantu (2012) identified three STEM approaches that can be applied in learning, namely silo, embedded, and integrated approaches. The silo approach teaches each discipline (Science, Technology, Engineering and Maths) to strengthen knowledge in each field. The embedded approach emphasized real-world situations and problem-solving strategies. Meanwhile, the integrated approach combines two or more disciplines in an integrated manner. Adopting a multidisciplinary approach can broaden students' horizons and help them recognize the interconnections between mathematics and other disciplines (Goos et al., 2023).

The dimension of the need for teaching materials obtained a low average score (2.67 and 2.33) with the category 'Low,' indicating that the teaching materials used by teachers today do not fully support the strengthening of numeracy or contextualization of material. This is an important basis for developing teaching materials that meet the needs, namely teaching materials based on the STEM-RME approach that are contextualized, support numeracy, and increase student efficacy. Finally, all teachers (100%) reported access to ICT facilities that support learning, but only 63% of teachers demonstrated the ability to use digital media in their teaching. This indicates that most teachers already have access to digital technology, but there is a need for support and training for teachers to effectively implement these approaches in classroom practice.

Interviews with several mathematics teachers confirmed the quantitative findings related to numeracy problems and students' self-efficacy. Teachers consistently reported that many students have difficulty in understanding mathematical concepts deeply, especially when it comes to applying the concepts in a real context. One teacher stated, 'Students often feel afraid of being wrong when doing problems, so their confidence decreases and has an impact on learning outcomes.' This statement reinforces the importance of paying attention to self-efficacy as a major factor in successful mathematics learning.

In addition, teachers also emphasized the need for innovative learning strategies and interesting media to help students develop numeracy more effectively. Some teachers admitted that they still find it difficult to integrate STEM and RME approaches optimally in their daily learning. This is in line with the results of the analysis showing low scores on mastery of STEM-RME integration, where teachers expressed the need for further training to understand and apply the two approaches in an integrated manner.

In terms of teaching materials, teachers stated that the materials currently available are not fully able to facilitate contextualized learning and strengthen students' numeracy. One teacher added, The existing teaching materials tend to be theoretical and do not challenge students to think critically and creatively.' This condition confirms the urgent need to develop STEM-RME-based teaching materials that are not only contextualized but also able to increase students' motivation and confidence.

Finally, technology support received a positive response from teachers. They revealed that although some are already accustomed to using technology in learning, access and utilization of digital technology still need to be supported with easy-to-use and interesting learning resources, such as digital-based e-modules. This provides a great opportunity for the development of innovative and interactive learning media to answer the current needs of teachers and students. Thus, the interview results strengthen the picture of teachers' needs for the development of learning media and strategies based on contextualized and digital STEM-RME approaches, as well as the need to increase teachers' capacity in implementing these approaches effectively.

This condition is a strong foundation for the development of STEM-RME-based mathematics e-modules. The STEM-RME approach can bridge this gap because: (1) integrates real contexts that help students understand the application of numbers and mathematical symbols in everyday life, (2) presents learning that links science, technology, engineering, and mathematics in an integrated manner, which can improve data analysis and interpretation skills, and (3) provides meaningful learning experiences through realistic problem-solving activities that encourage the development of data-based decision-making skills. E-modules with this approach are expected to effectively improve students' numeracy, which currently still requires serious attention.

The e-module based on STEM and RME will be designed to transform traditional mathematics learning into an engaging and interactive experience. As the integration between STEM and RME includes the four STEM disciplines and the

distinctive features of RME, this E-module will be equipped with the following features.

1) Interactive videos that demonstrate mathematical concepts in a real-world context.
2) Problem-solving scenarios that integrate several STEM disciplines.
3) Dynamic visualization tools to enhance conceptual understanding.
4) Collaborative learning activities can increase student engagement and knowledge sharing between students.
5) An adaptive assessment system that provides feedback.
6) Interactive and engaging exercises or quizzes.
7) User-friendly interface that facilitates self-learning.

CONCLUSION

Based on the results of the needs analysis conducted on students and mathematics teachers at the senior high schools, it can be concluded that the development of STEM-RME-based e-modules is required to support the improvement of students' numeracy. Test results show that the students' numeracy mastery is still low on various indicators, especially in terms of data interpretation, the use of mathematical symbols, and decision making based on quantitative information. On the other hand, both students and teachers showed high interest in the use of interactive, contextualized, and accessible digital learning media. Students expect e-modules that have an attractive yet simple appearance, communicative language, easy navigation, and provide interactive practice questions with immediate feedback. Teachers also emphasized the importance of e-modules that are aligned with the curriculum, contain contextual learning approaches, and can accommodate individual student needs. Thus, the results of this analysis provide a strong basis for the development of STEM-RME-based mathematics e-modules that are not only pedagogically relevant but also responsive to the real needs in the field.

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