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Development of algebraic expressions e-modules through realistic mathematics education approach

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Abstract

Students often struggle with algebraic expressions due to the abstract nature of mathematical symbols. The Realistic Mathematics Education (RME) approach offers an alternative to help students solve these problems. This study aimed to develop a valid, practical, and effective e-module based on the RME approach, incorporating video triggers, live worksheets, learning trajectories, and assessments for teaching algebraic expressions. The research followed Plomp's development models, including preliminary, prototyping, and assessment phases, with two groups of students (control and experimental). The results showed that the e-module was valid, receiving average scores of 4.68 and 4.8 from media and material experts, while the inter-rater reliability demonstrated substantial agreement (κ = 0.654), indicating a high level of consistency. The practicality of the e-module was demonstrated through teacher and student response questionnaires, which indicated that the RME-based e-module is practical for use in learning. The e-module's effectiveness was evidenced by the learning outcomes, which showed a significant difference (p = 0.015, Cohen's d = 0.65), indicating a moderately strong effect on student learning outcomes. These findings contribute to the advancement of digital mathematics learning resources and highlight the potential of RME-based interactive e-modules to enhance students' understanding of algebraic expressions.

Keywords:
Algebraic expression, E-module, Realistic mathematics education

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1. INTRODUCTION

Technology is a tool to collect, organize, evaluate, and innovate learning (Jimoyiannis, 2010; Young, 2017). Advances in technology have significantly impacted various fields, including education. Integrating technology into education provides numerous opportunities for teachers to deliver learning materials to students effectively. Incorporating technology in learning supports and enhances the teaching and learning process (Higgins et al., 2012). Ultimately, technology application in education positively influences students' learning experiences.

One approach to designing technology-based learning is using learning media that support student comprehension. Learning media are tools or instructional materials designed to stimulate students' attention, interest, and cognitive engagement, thereby achieving learning objectives (Prasetyo et al., 2020; Puspitarini & Hanif, 2019). These media serve as intermediaries for delivering information via text, audio, or video between the sender and receiver (Buckingham, 2007; Smaldino et al., 2009). The primary purpose of learning media is to facilitate and improve the learning process (de Siqueira et al., 2016). E-modules are one of the effective tools (Komikesari et al., 2020). They are electronic teaching materials designed to support interactive learning. They enable teachers to present material to students more engagingly, aligning with technology advancement. The content in e-modules is delivered through text and diverse formats such as videos, audio, animations, and other multimedia (Herawati, 2017; Kismiati, 2020). E-modules support independent learning, allowing students to study at their own pace, whether at school or home. Additionally, using e-modules promotes active learning and enhances problem-solving skills (Setiyani et al., 2022), particularly in mathematics instruction for algebraic expressions.

Algebraic expressions are a branch of algebra that involves simplification and problem-solving using substitute symbols, including constants and variables. Algebra is a crucial topic in mathematics education as it plays a significant role in understanding everyday life and influencing decision-making processes (Hall, 2002; Usiskin, 1995). Moreover, algebra is foundational for fostering abstract thinking (Witzel et al., 2003). It begins with basic arithmetic and progresses to more complex algebraic processes, often posing challenges for students (Baroudi, 2006; Sarımanoğlu, 2019). Students frequently exhibit misconceptions when interpreting variables, algebraic expressions, equations, and word problems (Egodawatte, 2011). Common errors include misunderstanding the symbol "+" as universally additive, leading students to simplify $3x + 4$ as $7x$ or $4 + 3x^2$ as $7x^2$ (Chow & Treagust, 2013). Research has shown that a limited understanding of algebra can hinder students’ ability to learn advanced mathematical concepts (Booker, 1987; Brandell et al., 2008; Hiebert et al., 2005). Similarly, Rudyanto et al. (2019) found that students often struggle with basic algebra, particularly regarding the meaning of variables in algebraic operations. As such, algebra warrants special attention in mathematics education.

Students’ understanding of algebraic expressions requires an approach that links abstract mathematical concepts to meaningful contexts. One promising approach to improving students' understanding of algebraic expressions is the Realistic Mathematics Education (RME) approach (Musyrifah et al., 2023). RME addresses challenges arising from the abstract nature of mathematics by integrating realistic and meaningful problems into the learning process (Bray & Tangney, 2015). The approach encourages students to solve problems informally and gradually guides them toward formal mathematical thinking through teacher facilitation (Gravemeijer, 1994; Laurens et al., 2017; van den Heuvel-Panhuizen & Drijvers, 2020). Freudenthal, the founder of RME, emphasized that this method requires students to re-invent mathematical ideas, such as concepts, strategies, procedures, formulas, and definitions under teacher guidance (Freudenthal, 1971, 1991). Therefore, RME supports students in developing a deeper conceptual understanding of algebraic expressions.

Integration of digital teaching materials with the RME approach has significant potential to enhance the effectiveness of mathematics learning. Previous research highlights the potential of digital teaching materials, such as digital books (flipbooks), lesson plans, and worksheets, developed with the RME approach to enhance problem-solving skills and promote student independence in mathematics learning (Diarta et al., 2021; Gea et al., 2022; Heriyadi & Prahmana, 2020; Lestari et al., 2023; Palinussa et al., 2024; Sutarni et al., 2024; Weng et al., 2018). The development of e-modules for arithmetic and circle topics using tools like Wordwall games, Liveworksheets, Google Forms, and Sigil applications has demonstrated the practicality and appeal of e-modules in mathematics education (Safitri et al., 2022). Similarly, Benitha and Novaliyosi (2022) found that e-modules for algebra, developed with the RME approach and supported by applications such as Microsoft Word, Canva, Heyzine, and Flipbook Maker, enhanced the attractiveness of the learning process. However, Yuhasriati et al. (2022) noted that students' mathematical representation skills in algebraic expression learning using the RME approach remain low, primarily due to insufficient mastery of prerequisite materials, such as integers. Algebra is recognized as a subject that is not only difficult to learn but also challenging to teach effectively (Stacey et al., 2004; Watson, 2009). As a result, many students struggle with learning algebra (Booth, 1988; Drijvers, 2004; Herscovics & Linchevski, 1994; Kolovou, 2011; Warren, 2003). The use of e-modules based on the RME approach can support students in developing a deeper understanding of mathematical concepts through real-world contexts and active exploration, thereby enhancing their problem-solving skills. Furthermore, the practicality and flexibility of e-modules make them an effective tool to support problem-based learning and to foster students' critical thinking skills (Reiss & Törner, 2007). Therefore, further innovation is needed to strengthen students' conceptual understanding through the development of interactive e-modules based on the RME approach, particularly in the area of algebraic expressions.

Based on previous studies, e-modules for algebraic expression using the RME approach have been developed by integrating various applications. However, previous research has placed greater emphasis on technological aspects, whereas attention to enhancing students' cognitive skills in algebraic expressions has remained limited. Therefore, the novelty of this study lies not only in the integration of applications but also in the development of algebraic content that is contextual, cognitively demanding, and aligned with the principles of RME. This e-module was developed using applications such as Liveworksheet, Video Animaker, Canva, and Quizizz. These applications were selected for their complementary functions: Liveworksheet supports interactive learning, Video Animaker facilitates the visualization of abstract concepts, Canva enhances visual representations to increase engagement, and Quizizz provides formative assessment. This research presents an RME-based e-module that supports teachers in effectively teaching algebraic expressions and enhances student engagement and learning outcomes. Consequently, the research problem of this present study is: What are the validity, practicality, and effectiveness of RME-based e-modules for teaching algebraic expressions?

2. METHOD

This study employed a development research design. According to Gall et al. (1996), development research is a systematic process to create and validate educational products. The process includes reviewing existing research findings, developing the product based on them, testing it, and revising it based on field test results. The development model applied in this study follows Plomp's framework (2013), which was selected to produce learning tools that meet the criteria of validity, practicality, and effectiveness (Nieveen, 1999). The model aligns with the research objective of developing an RME-based e-module on algebraic expressions through three stages: preliminary research, prototyping phase, and assesmen phase.

Pleminary Research

In the preliminary research phase, several activities were undertaken, including undertaking the need analysis of teachers and students for e-modules, conducting surveys at selected schools, reviewing relevant literature, and identifying the content requirements for the e-modules. The needs analysis revealed a strong interest among teachers and students in using e-modules for algebraic expressions and highlighted the necessity of developing e-modules through the RME approach. The literature review further confirmed that no e-modules for algebraic expression incorporating Canva, Liveworksheet, Animaker, Google Forms, and Quizizz have been developed.

Each application served a specific purpose in the development of the e-module. The Canva application was used to create visually appealing module designs, student worksheets, and videos. Liveworksheet facilitates the creation of interactive online worksheets. Animaker enabled the development of animated videos with characters and visuals tailored to the subject content. Google Forms was used to design comprehension check questionnaires to assess students' understanding of each subtopic in the student worksheet. Additionally, quizizz provided an interactive platform for creating online quizzes as evaluation tools at the end of the learning process.

Prototyping Phase

During the prototyping phase, the initial design of the e-module (prototype I), a validation sheet, and teacher and student response questionnaires were developed. The design of the prototype I involved creating the content, videos, and interactive worksheets using Liveworksheet, comprehension checks and question lists with Google Forms, and evaluation quizzes with Quizizz. The content of the e-module was adapted from resources provided by the Research Center for Realistic Mathematics Education Indonesia (PRP-PMRI) at Universitas Syiah Kuala, Indonesia. The e-module on algebraic expressions, developed through the RME approach, represented prototype I. It consisted of 15 pages, designed with navigation buttons to facilitate user interaction, with each page providing structured content that can be accessed intuitively. The navigation buttons aim to enhance usability, as outlined in Table 1.

Table 1. Buttons on the e-module and their functions

No.	Button Image	Function
1.		to navigate to the table of contents
2.		to open a video trigger before working on the student worksheet
3.		to open the live worksheet page according to the material on the page opened
4.		to open the Google form page to evaluate students' understanding of the previous lesson
5.		to accommodate questions that students might ask about content they do not understand or about how to navigate the e-module.
6.		to open the quizziz page for evaluation

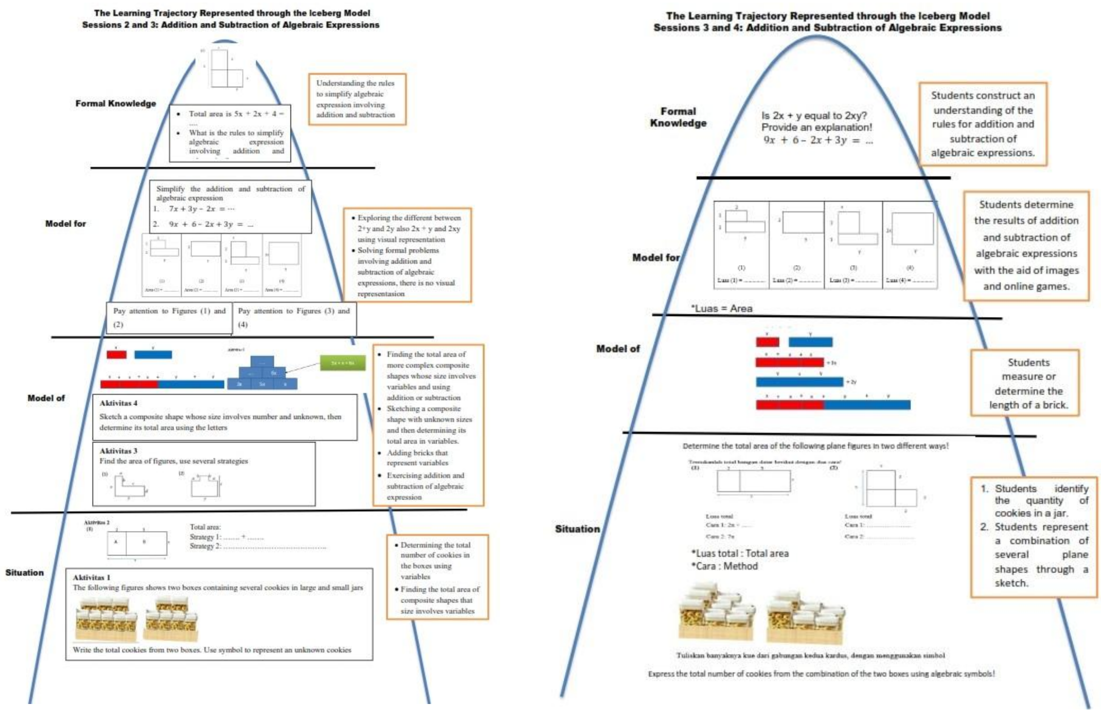
This e-module provides four video button menus containing different learning video displays (see Figure 1). The four videos aimed to trigger students to continue learning activities and work on student worksheets.

Figure 1. Video display overview

The student worksheet for the six meetings was designed using canva and liveworksheet applications (see Figure 2). It can be completed directly on the live worksheet page, and teachers can access student answers through the live worksheet account. The activities on the student worksheet were adapted from the book chapter developed by the PRP-PMRI team at Universitas Syiah Kuala. The display of the e-module opens on a separate tab page because Heyzine does not support the live worksheet format.

Figure 2. Student worksheet display overview from Canva

In the first and second meetings, the learning objectives were for students to write examples of algebraic expressions and identify variables, coefficients, and constants in an equation. In the third and fourth meetings (see Figure 3), students were expected to determine the rules for adding and subtracting algebraic terms. Finally, in the fifth and sixth meetings, the learning objectives focused on enabling students to derive the rules for multiplying algebraic expressions.



(a) before revision (b) after revision

Figure 3. Learning trajectory of the third and fourth meetings of learning algebraic expressions

The learning trajectory developed in this study was adapted from the research by Yuhasriati et al. (2022), which examined students' mathematical representation skills in algebraic expressions. The findings indicated that students' mathematical representation skills were low. Consequently, this study refined the learning trajectory to enhance students' understanding of algebraic expressions. At this stage, the e-module was validated by five validators, including four media experts and one material expert. E-modules deemed feasible for implementation were subsequently tested for practicality and effectiveness.

Assesmen Phase

In this phase, the practicality and effectiveness of the e-module were evaluated. The practicality test was assessed based on the responses of teachers and students to the e-module. A response questionnaire was distributed to 30 students and one mathematics teacher via Google Forms. The effectiveness of the e-module was tested based on students' learning outcomes involving two Year 7 classes: a control group and an experimental group. The experimental group is taught using the e-module, while the control group follows the traditional teaching method. Student performance was measured using average scores and the percentage of students achieving the minimum criteria of mastery learning. If the experimental group demonstrates significantly performance compared to the control group, the module is deemed effective.

2.1. Research Subject

This study involved nine students for the e-module readability test, 30 students for the response questionnaire, and one mathematics teacher for the teacher response questionnaire. Additionally, 58 seventh-grade junior high school students participated, comprising a control class (n = 28) and an experimental class (n = 30). Schools were selected using a cluster random sampling technique based on the availability of adequate learning facilities and teacher readiness to implement the e-module. Two classes with relatively balanced abilities were randomly selected from the school that met the criteria. Among the 58 students, there were 30 female students (51.7%) and 28 male students (48.3%) with an age range of 12-13 years. These data indicate that the study sample reflects the diversity of student demographics and is therefore representative for evaluating the effectiveness of the RME-based e-module on algebraic expressions.

2.2. Research Instrument

The instruments used in this study included validation sheets, teacher and student response questionnaires, and mathematics tests. The validation sheets were provided to validators comprising media and material experts. Teacher and student response questionnaires were employed to assess the practicality of the e-module, while the learning outcomes tests were administered to evaluate the module's effectiveness.

2.3. Data Collection Procedure

The study was conducted over six face-to-face meetings with two classes at a junior high school in Aceh, Indonesia. A pilot test of the e-module was carried out to assess its effectiveness. Following the pilot test, students completed a test to evaluate their learning outcomes. Data were collected from the validation results provided by media and material experts, response questionnaires, and student learning outcomes tests consisting of 10 multiple-choice questions. The practicality of the e-module was determined from teacher and student responses, while its effectiveness was assessed based on the mathematics test results.

2.4. Data Analysis

Data was analyzed using validation sheets, readability questionnaires, response questionnaires, and mathematics tests. Product development quality was evaluated based on validity, practicality, and effectiveness criteria, as defined by (Nieveen, 1999). The e-module validation involved five experts selected based on their areas of expertise: two RME specialists, two media design experts, and one mathematics education lecturer. The validation data from material and media experts was then analyzed to determine whether the e-module met the minimum criteria to be eligible for use. A detailed description of the average scores is provided in Table 2.

Table 2. Assesment criteria for e-module validity

Interval Score	Criteria
$\bar{x} > 4.2$	Excellent
$3.4 < \bar{x} \leq 4.2$	Good
$2.6 < \bar{x} \leq 3.4$	Fair
$1.8 < \bar{x} \leq 2.6$	Poor
$\bar{x} \leq 1.8$	Very Poor

Source: Morgan (2011)

The validators’ assessments were analyzed using a validation sheet, and inter-rater reliability was measured with Fleiss’ Kappa to ensure consistency among the validators. The resulting scores indicate the level of agreement on the aspects assessed in the e-module, thereby strengthening the credibility of the validation results. The interpretation criteria for the Fleiss’ Kappa scores are presented in Table 3.

Table 3. Interpretation of Fleiss' Kappa Value (κ)

κ - value	Reliability Level
< 0.00	Poor
0.00 - 0.20	Slight
0.21-0.40	Fair
0.41-0.60	Moderate
0.61-0.80	Substantial
0.81-1.00	Almost Perfect

Source: Landis and Koch (1977)

Readability test was conducted to assess the feasibility of the e-module. This test involved nine students, divided into small groups. Data from the readability test were analyzed descriptively to determine the extent to which the language, terminology, content, and presentation of the e-module were comprehensible to the initial users. The results of the readability test were then used to revise the e-module prior to evaluating its practicality.

The practicality of the RME-based e-module was assessed using teacher and student response questionnaires, indicating that the developed e-module was easy to use in the learning process. The questionnaire was structured around several aspects, including ease of use, practicality of presentation, readability and language, and timeliness. It was completed by 30 students and a mathematics teacher. Data from both teacher and student responses were analyzed using measures of central tendency, including median, mode, and percentile, to ensure that the interpretation aligns with the ordinal nature of the data. Practicality criteria were determined based on commonly used Likert scale interpretation guidelines. The 1–5 score range was divided into five categories, from ‘strongly agree’ to ‘strongly disagree’ (Allen & Seaman, 2007; Blaikie, 2003; Jamieson, 2004). The e-module is considered practical if the median, mode, and percentile (P75) fall within the ‘agree’ category. The effectiveness of the e-module on algebraic expressions was evaluated using an independent samples t-test to compare learning outcomes between the control and experimental groups. This analysis aimed to determine whether there was a significant difference in the mean post-test scores between the two groups. The assumptions for conducting the t-test were assessed using normality and homogeneity of variance tests in SPSS. A significance value of $p > 0.05$ indicated that the data were normally distributed, allowing the use of parametric statistical tests. The research hypotheses tested were as follows:

H_0 : There was no significant difference in the mean learning outcomes between students in the experimental and control groups

H_1 : There was a significant difference in the mean learning outcomes between students in the experimental and control groups.

In addition to the significance value, the effect size of the mean difference between groups was calculated using Cohen’s d, allowing the interpretation of the results to consider not only statistical significance but also the magnitude of the intervention effect. The interpretation of Cohen’s d values is presented in Table 4.

Table 4. Cohen's d interpretation

d - value	Effect Size Level
0.20 - 0.49	Small Fffect
0.50 – 0.79	Medium Effect
≥ 0,80	Large Effect

Source: Cohen (2013)

3. RESULTS AND DISCUSSION

3.1. Results

The e-module was developed by adopting the Plomp (2013) model, comprising three stages: preliminary research, prototyping, and assessment. This development process resulted in an e-module on algebraic expressions using the RME approach that is valid, practical, and effective.

3.1.1. Validity

The validation results from media experts indicate that the developed e-module was categorized as excellent. The average scores provided by the validators were 4.93, 4.53, 4.57, and 4.67, with an overall average of 4.68. A more detailed analysis based on specific indicators is presented in Table 5.

Table 5. Media expert validation results

Indicator of material validation	Mean ($\overline{x}$)			
	V1	V2	V3	V4
Screen design appearance	4.8	4.6	4.6	4.8
Ease of Use	5	4.8	4.5	5
Consistency	5	4.7	4.3	4.7
Usefulness	5	4.4	4.6	4.6
Graphics	5	4.5	4.8	4.8
Video content	4.8	4	4.3	4.8
Video appearance	4.9	4.6	4.4	4.8
Construction	5	4.3	4.7	4.5
Content	4.8	4.5	4.5	5
Language	4.8	4.8	4.8	3.8
Presentation	5	4.8	4.5	5
Design	5	4.9	4.7	4
Ease of Use	5	4.3	4.7	4.7
Material	5	4.3	4.7	5
Mean	4.93	4.53	4.57	4.67
Category	Excellent	Excellent	Excellent	Excellent

The validation results by material experts revealed a total average of 4.8 (excellent category). The validation results for each indicator are more specifically shown in Table 6.

Table 6. Material expert validation results

Indicator of material validation	Mean ($\overline{x}$)	Category
Content Eligibility	4.7	Excellent
Language	4.8	Excellent
Presentation	4.8	Excellent

Table 6 indicates that the e-module was deemed feasible. Furthermore, the validators suggested revisions to include learning objectives, learning outcomes, and adjustments to the font size. The revised version of the e-module is shown in Figure 4.

Figure 4. Display of the e-module for algebraic expressions

Inter-rater reliability was calculated using Fleiss' Kappa. The results showed an average observed agreement ($\bar{P}$) = 0.934 and an expected agreement (P_e) = 0.81, yielding a Fleiss' Kappa value (κ) of 0.654. According to Landis and Koch's (1977) interpretation criteria, this value falls into the substantial agreement category, indicating a high level of consistency among the validators in assessing the quality of the developed media.

In addition to expert validation, a readability test was conducted with seventh-grade students to assess the extent to which the e-module was easy to read and understand. Student responses to the e-module are presented in Table 7.

Table 7. Student comments

Aspect	Comments/Responses	Revision Decision
Readability	The language is ambiguous and difficult to understand	The e-module was revised using language that is simpler, clearer, and easier for students to understand
Format	The layout is cluttered and appears monotonous	The e-module was presented with a neater and more engaging layout, reducing the sense of monotony
Material	The material is presented with numerous algebraic symbols, making it difficult to understand	The e-module was revised by simplifying the presentation of algebraic material, which helped students better understand the e-module

Table 7 presents students' comments regarding the readability, format, and presentation of the e-module material. Several sentences were considered ambiguous and difficult to understand, necessitating revisions using simpler, clearer, and more comprehensible language without altering the substance of the content. Additionally, the previously cluttered and monotonous layout of the e-module was improved with a more concise and engaging design to avoid boredom. Material that was initially presented with numerous algebraic symbols was also simplified, enabling students to better understand the e-module's content. These revisions highlight the importance of readability testing to ensure that the e-module can optimally support students' understanding.

3.1.2. Practicality

During the assessment stage, field trials were conducted with Year 7 students at a junior high school in Banda Aceh, Indonesia. The practicality of the e-module was evaluated using research instruments, including a student response questionnaire distributed via Google Forms to 30 students and a teacher response questionnaire. The results of the e-module assessment are summarized in Table 8.

Table 8. Summary of practicality test results

Statistic	Teacher (Value)	Student (Value)	Interpretation
Median	4	4	Teacher and student evaluations fell within the 'agree' category, indicating that the e-module is practical to use.
Mode	4	4	The most frequent score was 'agree,' reinforcing the consistency of the e-module's practicality
Percentile 75 (P75)	5	4	The teacher gave a 'strongly agree' rating, while the students rated the e-module as 'agree' regarding its practicality

The data in Table 8 indicate that the RME-based e-module on algebraic expressions was considered practical by both teachers and students. This is reflected in the median and mode, both of which were 4 ('agree'), indicating that the majority of respondents found the e-module easy to use in learning. The percentile distribution further supports this finding, with one-quarter of the students still at the 'agree' level, while most teachers rated it as 'strongly agree.' These results demonstrate that the RME-based e-module is practical and suitable for use in teaching algebra.

3.1.3. Effectiveness

The effectiveness of the e-module was assessed to evaluate its success in facilitating learning activities. An e-module is deemed effective if it positively impacts student learning outcomes. In this study, student learning outcomes were evaluated through test scores and the achievement of minimum criteria of mastery learning. Prior to conducting further statistical tests, the assumptions of normality and homogeneity were assessed. The results of the normality and homogeneity tests are presented in Table 9.

Table 9. Normality test of students' learning outcomes

Class	Statistic	df	Sig.
Control	0.960	28	0.347
Experiment	0.977	30	0.734

Table 10. Homogeneity test of students' learning outcome

Levene's Statistic	df1	df2	Sig.
4.333	1	56	0.050

Based on Tables 9 and 10, the significance values (Sig.) for both the control and experimental groups were greater than 0.05. This indicates that the data were normally distributed and had homogeneous variances, thereby meeting the requirements for parametric statistical testing. The result of T-test was presented in Table 11.

Table 11. T-test results of postest scores

Class	Mean (M)	Standard Deviation (SD)	*t*	*df*	*p*
A (control group)	67.7	4.61	-2.48	56	0.015
B (experiment group)	72	8.05			

The results of the t-test analysis of student learning outcomes in the control group (Class A) and experiment group (Class B) revealed that the average test score Class A (M=67.68, SD=4.61) and Class B (M=72.00, SD=8.05) are significant difference $t(56) = -2.48$, $p < 0.05$). Therefore, it can be concluded that the use of the RME-based e-module has a significant effect on improving students' learning outcomes in algebraic expressions. In addition, the higher standard deviation observed in the experimental group indicates variation in learning outcomes among students. This variation may be influenced by differences in students' engagement with the e-module as well as their initial abilities. The implications of these findings suggest that, although the e-module is effective in enhancing learning outcomes, supplementary strategies are needed to ensure a more consistent effect across all students.

The effect size was analyzed to determine the magnitude of the e-module's impact on students' learning outcomes. The effect size, calculated using Cohen's d was 0.65, which falls into the medium category. This indicates that the use of the e-module had a moderately strong effect on improving students' learning outcomes.

3.2. Discussion

The e-module development process in this study adopted Plomp's (2013) development model. The analysis revealed that the RME-based e-module met the valid, practical, and effective criteria. This e-module includes several features, such as a video trigger menu, learning trajectory, live worksheets, and assessments. It facilitates independent learning for students and is accessible at school and home. This indicates the practicality of the e-module as a tool for independent learning without relying entirely on the teacher. Its practicality is also reflected in students' active engagement in group discussions when using the Liveworksheet feature, which further enhances the e-module's effectiveness in supporting learning activities. Trilestari and Almunawaroh (2021) also found that e-modules can serve as an independent learning solution through problem-solving activities and learning videos that enhance material comprehension. Similarly, Sholikhah et al. (2022) found that e-modules improve student learning outcomes and support independent learning during distance education. This shows that the development of RME-based e-modules is in line with previous research which confirms the role of e-modules in supporting student learning independence and improving the quality of learning.

The RME approach emphasizes presenting problems relevant to students' experiences and knowledge. Contextual problem-solving activities positively impact student achievement, particularly in understanding mathematics (Bonotto, 2010). The findings of this study indicate that students find it easier to understand algebraic expressions when presented with contextual problems through trigger videos and are more actively engaged in constructing understanding through Liveworksheet activities. The RME principles emphasize knowledge construction through real-world contexts, which has a significant effect on enhancing students' understanding. This demonstrates the effectiveness of the e-module, as reflected in the improvement of students' comprehension of algebraic expressions, particularly in overcoming difficulties with symbolic manipulation and algebraic procedures.The implementation of RME principles in this e-module is not limited to contextual presentation and has been systematically integrated through the developed Iceberg model. This model guides students through a progressive thinking process, as illustrated in Figure 3b. At the Situation stage, students determine the number of cookies in a jar and draw sketches of combined flat shapes. In the Model of stage, students determine the length of bricks as a manipulative representation of algebraic concepts. Subsequently, at the Model for stage, students model the results of addition and subtraction of algebraic terms using visual aids and online games. Finally, at the Formal Knowledge stage, students achieve symbolic understanding by discovering the rules for adding and subtracting algebraic terms. Thus, the Iceberg model plays a significant role in deepening students' conceptual understanding and reducing obstacles encountered when learning abstract algebraic concepts. Similarly, Bray and Tangney (2015) stated that the RME approach is capable of addressing the challenges of teaching abstract mathematics, particularly in the topic of algebraic expressions. Students often struggle with algebra due to difficulties in symbol manipulation and procedural understanding, leading to superficial comprehension (Chazan, 1996; Kieran, 1992). The RME-based e-module positively influenced student learning outcomes in algebra, as evidenced by the improvement in posttest scores and the increased number of students achieving learning mastery.

The application of the e-module demonstrated its effectiveness in two classes. Students who used the RME-based e-module demonstrated better mastery of algebraic expressions compared to students taught using conventional methods. These findings indicate that the integration of real-world contexts in the learning process helps students build a stronger conceptual understanding. Research by Kurniansyah et al. (2022) and Purnomo et al. (2024) similarly highlighted that e-modules encourage improved learning outcomes. Moreover, using e-modules with contextual problems positively impacts student understanding (Azizah et al., 2020; Leow & Neo, 2014; Ramadhan et al., 2019; Salavera et al., 2019; Voithofer, 2005). In addition to improving learning outcomes, the effectiveness of the e-module is also reflected in positive responses from both students and teachers. Students reported that using the e-module with trigger videos and Liveworksheet activities made learning more engaging, interactive, and easier to understand, particularly for algebraic expressions, which are often considered difficult. Teachers also responded positively to the e-module, noting that it facilitated the presentation of material relevant to real-world situations and supported a learning process focused on the gradual construction of knowledge. These features reflect the principles of RME. For instance, trigger videos provide real-world contexts that guide students through the process of guided reinvention, while the use of Liveworksheet supports students in independently developing problem-solving strategies before reaching formal representations. This highlights that the practicality and effectiveness of the e-module are not only reflected in test results but also in users' experiences in the field. Therefore, the implementation of the e-module using the RME approach in teaching can serve as a solution to enhance learning outcomes, student engagement, and learning activities.

The development of this e-module is expected to assist teachers and students in creating a more interactive learning environment while providing accessible learning resources tailored to students' needs. However, due to the authors' constraints, this study's evaluation was limited to a small-scale implementation. Future research should extend the application of the developed e-modules to a broader range of participants to ensure greater comprehensiveness and applicability across diverse learning scenarios. Furthermore, this study addresses a research gap, as the integration of RME principles into digital learning resources for algebraic expressions remains limited. The main contribution of this study demonstrates that combining RME with digital modules not only strengthens the theoretical foundation but also produces practical tools ready for use by teachers. Consequently, RME-based e-modules can serve as an innovative alternative to enhance student engagement, deepen conceptual understanding, and improve learning outcomes.

4. CONCLUSION

This research produces an e-module on algebraic expressions based on the RME approach. Based on the findings and discussion, it can be concluded that the RME-based e-module is valid, practical, and effective for teaching algebra. This e-module presents problems grounded in studsents' daily experiences, making it easier for them to understand algebraic expression material. The e-modules, equipped with video triggers and assessments, have significantly improved student learning outcomes. By integrating algebraic concepts through interactive e-modules, students can develop a deeper understanding of algebraic expressions. As a result, this e-module serves as an effective teaching tool to create a more interactive and engaging learning environment for teaching mathematics, particularly algebraic expressions.

This study also provides a theoretical contribution by reinforcing the principles of Realistic Mathematics Education (RME), which posit that mathematical understanding develops from real-world contexts to model representations and ultimately to formal knowledge. The implementation of this e-module has been proven effective in helping students overcome difficulties in understanding abstract symbols and procedures in algebraic expressions. Theoretically, this confirms that integrating the RME approach into e-modules can extend the application of RME in algebra instruction and has important implications for mathematics teaching practices, emphasizing the construction of meaning through real-world contexts. However, this study has some limitations, as it only examines the impact of the e-module development on a limited scale and does not include large-scale dissemination testing. Therefore, future research is recommended to implement development on a larger scale and to explore its application in more diverse learning contexts.

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Declarations

Author Contribution	: RJ: Data curation, Formal analysis, Investigation, Methodology, Resources, Writing - original draft, and Writing - review & editing; DA: Data curation, and Formal analysis; M: Data curation, and Methodology; CMZ: Data curation, and Validation; TZ: Data curation; U: Data curation; LI: Data curation, and Writing - original draft; MM: Data curation.
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