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Development and Formative Evaluation of a Smart Apps Creator E-Module Using Pólya's Problem-Solving Stages for Grade 10 Trigonometry

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Abstract

Background of study: Grade 10 trigonometry requires digital resources that support reasoning, not merely transfer printed material to a screen.
Aims and scope of paper: This study developed and formatively evaluated a Smart Apps Creator e-module structured through Pólya's four problem-solving stages.
Methods: The study implemented seven stages adapted from the ten-step research-and-development procedure described by Sugiyono, potential and problems, data collection, product design, design validation, design revision, product testing, and product revision. Evidence comprised teacher input, 23 daily-test records, a Google Forms needs questionnaire whose respondent total was not recorded, validation by two media experts and two content experts, and responses from 21 Grade 10 students.
Result: Recalculation from the raw validation scores yielded media ratings of 91.7% and 93.3% (combined 92.5%) and content ratings of 92.5% and 76.3% (combined 84.4%). Student responses reached 79.2%. Expert revisions addressed navigation, readability, mathematical notation, content organization, problem-solving examples, images, and game functionality.
Conclusion: The e-module showed formative feasibility and perceived appeal in one school context. Its effectiveness for achievement or problem-solving performance was not tested.

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INTRODUCTION

Digital devices are increasingly embedded in students' daily lives, yet much mathematics learning still relies on static textbooks, teacher explanations, and chalkboard-centered activities. This presents an educational paradox: access to technology is increasing, but that access does not automatically translate into deeper mathematics learning. UNESCO GEM Report {2023) emphasizes that educational technology should be used to serve students' needs and achieve pedagogical goals, not simply because it is available. At the same time, the PISA 2022 results still indicate significant challenges in students' mathematical abilities across various education systems, particularly when they are faced with non-routine problems (OECD, 2023). The key issue is no longer whether schools should use digital technologies, but rather how these technologies are designed to support meaningful mathematical activities. A contextual meta-analysis shows that digital tools can have a positive impact on mathematics and science learning in secondary schools when integrated with appropriate learning strategies (Hillmayr et al., 2020). Conversely, technologies that simply transfer printed materials to screens risk perpetuating passive learning patterns. This tension makes the development of digital learning resources with a pedagogical structure a critical need in mathematics education.

This need was evident at SMA Plus Bina Mandiri based on a preliminary study conducted on May 31, 2023. Mathematics teachers explained that learning still relies on available textbooks, conventional modules, and lecture methods for delivering material. As a result, students tend to experience monotonous learning and are not optimally engaged in class activities. Documentation of daily test scores for trigonometry shows that only eight students, or 34.78%, achieved the minimum completion criterion of 70, while 15 students, or 65.22%, did not achieve this criterion. The results of the initial questionnaire also showed that 84.2% of students considered mathematics difficult to understand. The same percentage stated that trigonometry was one of the difficult topics. Despite this, 52.6% of students were interested in obtaining mathematics materials in digital format. These findings indicate a gap between the learning resources used and the forms of learning support needed and desired by students.

Trigonometry is relevant material for addressing this gap because it encompasses symbolic representation, geometric understanding, procedural knowledge, and contextual problem solving. Students must be able to connect angles, ratios, diagrams, identities, and equations, not simply apply formulas mechanically. Several studies have found that students still make mistakes in interpreting trigonometry word problems, determining relevant information, selecting solution procedures, and reviewing their answers (Aminudin et al., 2019; Wardhani & Argaswari, 2022). Difficulties also arise when students have not mastered prerequisite material or are unable to transform verbal and visual information into appropriate mathematical relationships (Agustini & Pujiastuti, 2020). Recent research on trigonometry modules emphasizes the importance of contextual tasks, conceptual organization, and guided problem-solving (Fitriwanti et al., 2023; Wati & Yerizon, 2024). A module that simply contains a collection of formulas without supporting students' thinking processes is likely insufficient to address these challenges. Interactive representations can connect diagrams, explanations, solution examples, and feedback directly within a single learning environment. Therefore, trigonometry provides a challenging yet relevant context for developing digital modules.

The problem-solving approach provides the pedagogical structure necessary to ensure that e-modules are not simply digital repositories of material. Pólya divides the problem-solving process into four stages: understanding the problem, planning a solution, implementing the plan, and reviewing the results (Polya, 2014). These stages can make the reasoning process, which is usually invisible, more explicit through guiding questions in examples, exercises, and evaluations. Numerous studies in mathematics education have shown that a structured problem-solving approach can help students identify known information, select strategies, carry out procedures, and evaluate answers (Arilaksmi et al., 2021; Husna et al., 2022). Research on problem-based learning also shows that learning materials become more productive when students are directed to interpret and solve meaningful mathematical situations (Siagian et al., 2019; Suparman et al., 2021). Multimedia learning theory provides a supporting perspective on how to combine verbal and visual information without overloading students' working memory (Mayer, 2020). The combination of multimedia presentation with problem-solving stages can support both cognitive processes and strategic behavior in solving math problems. This combination serves as the conceptual basis for developing this e-module.

A variety of international studies support the potential of mobile and interactive learning resources in education, although the results are not always consistent. A systematic review of mobile learning in mathematics and science shows that portability, accessibility, and multimodal presentation can support both classroom and independent learning, but the impact is largely determined by the task design used (Bano et al., 2018). Meta-analytic evidence also suggests that the integration of mobile devices in learning can improve student performance when the technology is used in targeted pedagogical activities (Sung et al., 2016). In mathematics learning, mobile technology is associated with improved student attitudes and achievement when used to explore concepts, not just receive information (Fabian et al., 2018). Digital games can also support learning achievement and motivation, although their effects vary based on level, intervention design, and form of assessment (Fadda et al., 2022; Tokac et al., 2019). Studies of mobile game-based learning also emphasize the importance of feedback, curriculum alignment, and cognitive challenges (Gao et al., 2020). Thus, digital modules must combine visual appeal with coherent content and a planned learning sequence. The literature supports technology-assisted mathematics learning, but discourages the use of technology without a clear learning structure.

Research in Indonesia is also increasingly developing electronic mathematics teaching materials and using Smart Apps Creator as a development platform. Smart Apps Creator has been used to develop Android-based mathematics media that has received positive reviews from experts and students (Amalia et al., 2022; Mahuda et al., 2021). Alpiani et al. (2022) reported that the Smart Apps Creator-assisted e-module on the material of sequences and series met the valid criteria for secondary school learning. Mutaqinah et al. (2024) also demonstrates that the Smart Apps Creator e-module is capable of presenting abstract geometry material as a valid and practical mobile learning resource. In other areas, Armela et al. (2024) demonstrated that the platform can integrate text, graphics, sound, exercises, and soft skills reinforcement into an interactive e-module. Other e-module development research has shown positive assessments of its feasibility and usability when the materials are systematically structured and refined based on expert input (Novera Kristianti, 2019; Yuberti et al., 2021). Problem-based mathematics e-modules have also been developed to support data presentation, local knowledge, and problem-solving skills (Maghfiroh et al., 2024; Putri et al., 2023; Ramadanti et al., 2021). These findings demonstrate the potential of interactive digital modules, but specific evaluation of the topics and designs used is still needed.

There are at least three limitations to previous research. First, some studies focus solely on technology platforms or learning approaches, while the integration of Smart Apps Creator with the Pólya problem-solving stages in high school trigonometry is still relatively limited. Second, product development reports often present only a single overall feasibility percentage, thus obscuring the distinction between media quality, mathematics material quality, and user response. Third, positive student responses are sometimes interpreted as evidence of effectiveness, even though the studies did not use a learning improvement measurement design. This distinction is important because attractiveness, feasibility, practicality, and effectiveness are different forms of evidence in educational design research (Plomp & Nieveen, 2013). Recent research on trigonometry and mathematics modules has begun to lead to clearer validation and measurement of problem solving, but still recommends wider implementation and testing of effectiveness (Maghfiroh et al., 2024; Wati & Yerizon, 2024). Transparent formative evaluation requires separating data from media experts, content experts, and students. Research must also accurately report calculations and limitations to avoid overstating findings. This gap defines this study's position in the literature.

Based on the description, this study aims to develop and formatively evaluate the Smart Apps Creator e-module for tenth-grade trigonometry learning, structured around four problem-solving stages. This study answers two questions: how the e-module was developed and revised, and how experts and students assessed the product's feasibility and appeal. Theoretically, this study contributes by linking multimedia learning principles and explicit problem-solving stages in mobile mathematics learning resources. Methodologically, this study separates media feasibility, material feasibility, and student appeal, preventing all positive results from being combined into a claim of effectiveness. Practically, this study produced a design containing materials, sample problems, interactive games, formative feedback, and evaluations that can be accessed via smartphones or computers. This study also provides contextual responses to student difficulties and the limited variety of learning resources in schools. The study's conclusions are limited to the formative quality of the product because the study did not measure improvements in learning outcomes. This position allows the product to be used as a basis for experimental research and evaluation on a broader scale.

METHOD

Research Design

This study used a research and development design to produce and formatively evaluate a mathematics e-module. The procedure adapted the ten-step R&D sequence described by (Sugiyono, 2020) and implemented seven stages: potential and problems, data collection, product design, design validation, design revision, product testing, and product revision. Usage testing, further product revision, and mass production were not conducted because of time and cost limitations. The design therefore provides formative evidence of product feasibility and student response, not causal evidence of effectiveness.

Table 1. Mapping of the modified ten-step R&D procedure to the seven implemented stages

Modified ten-step R&D procedure (Sugiyono, 2020)	Treatment in this study	Rationale/status
1. Potential and problems	Retained as Step 1	Teacher interview, score documentation, and needs questionnaire
2. Data collection	Retained as Step 2	Curriculum, trigonometry, and software references collected
3. Product design	Retained as Step 3	Initial Smart Apps Creator prototype produced
4. Design validation	Retained as Step 4	Two media and two content experts
5. Design revision	Retained as Step 5	Prototype revised from expert comments
6. Product testing	Retained as Step 6	One-class pilot with 21 Grade 10 students
7. Product revision	Retained as Step 7	Final review; no further change after "interesting" response
8-10. Usage testing, further revision, and mass production	Not conducted	Omitted because of time and cost constraints and the limited formative scope

Participant

The study involved two media experts, two content experts, and 21 Grade 10 students from SMA Plus Bina Mandiri. Selvi Loviana, M.Pd. and Nur Indah Rahmawati, M.Pd. served as media experts; Dwi Laila Sulistiowati, M.Pd. and Kiki Dwi Vatmala, S.Pd. served as content experts. The students used the revised product in the limited classroom trial and completed the 17-item response questionnaire. Additional demographic characteristics of the students were not recorded.

Population and the Methods of Sampling

The study did not define a wider target population or use probability sampling. The product trial was conducted in one Grade 10 class at SMA Plus Bina Mandiri, with complete questionnaire responses from 21 students. The class code, total class enrollment, formal inclusion and exclusion criteria, prior experience with the application or device, and overlap with preliminary-study respondents were not recorded. These details are therefore not inferred or added.

Instrumentation

Data were collected through a mathematics-teacher interview, daily-test documentation, a Google Forms needs questionnaire, media- and content-expert validation questionnaires, a student-response questionnaire, and screenshots documenting product revision. The daily-test documentation contained 23 student records, whereas the pilot response matrix contained 21 students. The needs questionnaire reported 84.2%, 84.2%, and 52.6%, but its total number of respondents was not stated. The three data sources served different purposes and are not treated as one sample.

Table 2. Data sources, denominators, timing, and evidential role

Data source	n	Timing/format	Purpose	Documented relationship
Daily trigonometry scores	23	May 31, 2023; teacher-held daily-test documentation	Initial performance diagnosis	One Grade 10 class; overlap with later groups not reported
Needs questionnaire	Not reported	May 31, 2023; Google Forms	Difficulty and interest in digital material	Respondent total not recorded

Media experts	2	12-item, five-point validation questionnaire	Media feasibility	Independent validator ratings
Content experts	2	16-item, five-point validation questionnaire	Content feasibility and Pólya stages	Independent validator ratings
Student pilot	21	One Grade 10 class; product use and 17-item questionnaire	Perceived appeal/acceptability	Exact overlap and reasons for count difference not reported

Instrument

The media-expert instrument contained 12 items covering ease of use, typography, sound, display, and integration. The content-expert instrument contained 16 items covering material, content, language, and Pólya's four stages. The student-response instrument contained 17 items covering content, presentation, language, attractiveness, and usefulness. All items used a five-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). Example indicators included ease of operating the e-module, readability of text, relevance and systematic organization of trigonometry content, and the presence of each Pólya stage. Construct-validity testing, inter-rater reliability coefficients, and internal-consistency coefficients were not reported. The instruments are therefore treated as formative appraisal instruments rather than psychometrically validated scales.

Procedures and Time Frame

The study was conducted at SMA Plus Bina Mandiri. The preliminary study took place on May 31, 2023 through a teacher interview, daily-test documentation, and a Google Forms needs questionnaire. The development process concluded in February 2024; separate dates for product design, expert validation, revision, and classroom trial were not recorded.

The product was an interactive Smart Apps Creator e-module for Grade 10 trigonometry. It covered angle measurement, trigonometric ratios in right triangles, related angles, trigonometric identities, and trigonometric equations. The interface included a cover, instructions, learning objectives, a material menu, examples, four learning games, multiple-choice and essay evaluations, and a developer profile. Pólya's four stages were incorporated into the revised worked examples and exercises.

Table3. Operational mapping of Pólya's stages in the e-module

Pólya stage	**Feature in revised example**	**Prompt/structure**	**Student action**	**Worked example used in the product**
Understand the problem	"Diketahui" and "Ditanya" fields	What is known and what must be found?	Identify given quantity and target unit	Known: 54 revolutions/minute; asked: revolutions/second
Plan a solution	Formula/conversion field	Which relationship converts the units?	Select 1 second = 1/60 minute	Use the minute-to-second conversion
Carry out the plan	Stepwise calculation area	How is the selected relationship applied?	Compute 54/60	54 rpm = 0.9 revolutions/second
Look back	Checking/conclusion field	Does the result answer the question and use the correct unit?	Restate and check the result	Conclude that 54 rpm equals 0.9 revolutions/second

The development followed seven stages. First, potential and problems were identified through the teacher interview, learning-resource review, daily-test documentation, and needs questionnaire. Second, curriculum material, Grade 10 mathematics references, and Smart Apps Creator resources were collected. Third, an initial prototype was designed with five content units, games, evaluations, and a user guide. Fourth, two media experts and two content experts validated the prototype. Fifth, the prototype was revised according to their comments. Sixth, 21 Grade 10 students used the product and completed the response questionnaire. Seventh, the product was reviewed after the pilot; no further revision was made because the aggregate response reached the "interesting" category.

Analysis Plan

Questionnaire scores were analyzed descriptively. Percentage scores were calculated using the following formula:

$$NP = (\frac{R}{SM}) \times 100\%$$

NP represents the percentage score, R the obtained score, and SM the maximum score. The expert-validation interpretation criteria are presented in Table 4.

Table4. Expert-validation interpretation criteria

Percentage interval	Interpretation
81–100%	Very feasible
61–80%	Feasible
41–60%	Moderately feasible
21–40%	Less feasible
<21%	Not feasible

Student percentages used parallel labels from very interesting to not interesting; these labels refer only to perceived attractiveness or acceptability, not learning quality. Scores by aspect, means, medians, and ranges were calculated from the completed 21 × 17 response matrix. These descriptive results are not presented as reliability coefficients or inferential statistics.

Scope and/or Limitations of the Methodology Used

The methodological scope was limited to expert validation and a product trial in one Grade 10 class at one school. The study did not use a comparison group, a pretest–posttest design, inferential analysis, an effectiveness test, a retention measure, or large-scale operational testing. The findings are therefore restricted to media feasibility, content feasibility, and students' perceived attractiveness or acceptability.

RESULTS AND DISCUSSION

Results

Preliminary needs and performance analysis

The preliminary study identified a mismatch between available resources, documented trigonometry performance, and students' interest in digital materials. Daily-test documentation from one Grade 10 class contained 23 records: eight students met the minimum score of 70 and 15 did not. The Google Forms charts reported 84.2% for mathematics difficulty, 84.2% for trigonometry difficulty, and 52.6% for interest in digital teaching materials. Because the questionnaire respondent total was not recorded, the percentages are reported without reconstructing respondent counts. The later pilot involved 21 students; participant overlap across these data sources was not recorded.

Developed product characteristics

The final prototype integrates curriculum content, problem-solving instructions, multimedia elements, and self-assessment activities into a single application. The main menu connects students to user manuals, objectives, units of content, games, evaluations, and developer profiles. Each unit of content includes explanations and examples structured around the stages of understanding the problem, planning a solution, implementing the plan, and checking answers. Four learning games were added to provide a variety of interactions and practice beyond the traditional sample questions. Multiple-choice assessments provide immediate feedback and scoring, while essay questions are written outside the application. The e-module can be used on smartphones and laptops, supporting both classroom use and independent learning. These features elevate the product beyond a static electronic document.

Expert validation

The media experts assigned 55/60 (91.7%) and 56/60 (93.3%), giving a combined score of 111/120 (92.5%). Their overall ratings differed by only one point. The content experts assigned 74/80 (92.5%) and 61/80 (76.3%), giving a combined score of 135/160 (84.4%). The larger difference in content ratings occurred mainly in the material, content-quality, and language aspects, whereas both experts rated the Pólya-stage component highly.

Table 5. Expert-validation results by aspect and validator

Domain/aspect	Maximum per validator	Validator 1	Validator 2	Combined percentage
Media - Ease of use	10	10	9	95.0%
Media - Typography	20	17	18	87.5%
Media - Sound	10	10	10	100.0%
Media - Display	10	9	9	90.0%
Media - Integration	10	9	10	95.0%
Media - Overall	60	55 (91.7%)	56 (93.3%)	111/120 (92.5%)
Content - Material	15	14	10	80.0%
Content - Content quality	25	23	16	78.0%
Content - Language	20	18	15	82.5%
Content - Pólya stages	20	19	20	97.5%
Content - Overall	80	74 (92.5%)	61 (76.3%)	135/160 (84.4%)

Reporting scores by aspect and validator prevents the combined percentages from concealing rating differences. Table 5 shows that media ratings were consistently high, while the content ratings indicated greater variation and therefore required closer attention during revision.

Product revisions

Expert comments led to revisions in navigation, readability, mathematical notation, problem-solving integration, content organization, and image clarity. Figure 1 presents representative before-and-after examples. Table 6 summarizes the key revisions; additional changes included brighter colors, clearer heading hierarchy, corrected text display, and revised usage instructions.

Table 6. Key product revisions after expert validation

Revision area	Issue identified	Revision made
Navigation	Arrow buttons were too small	Arrow buttons were enlarged for easier operation
Game readability	Game 2 text was difficult to read	The text and display were enlarged and clarified
Mathematical notation	The less-than sign (<) was used as an angle symbol	The notation was corrected to the angle symbol (∠)
Problem-solving integration	Examples and tasks did not explicitly show the four stages	Pólya's four stages were added to worked examples and exercises
Content organization	The five trigonometry subtopics were combined	The material was separated into five subtopics
Image clarity	The related-angle image was difficult to read	The image was enlarged and clarified

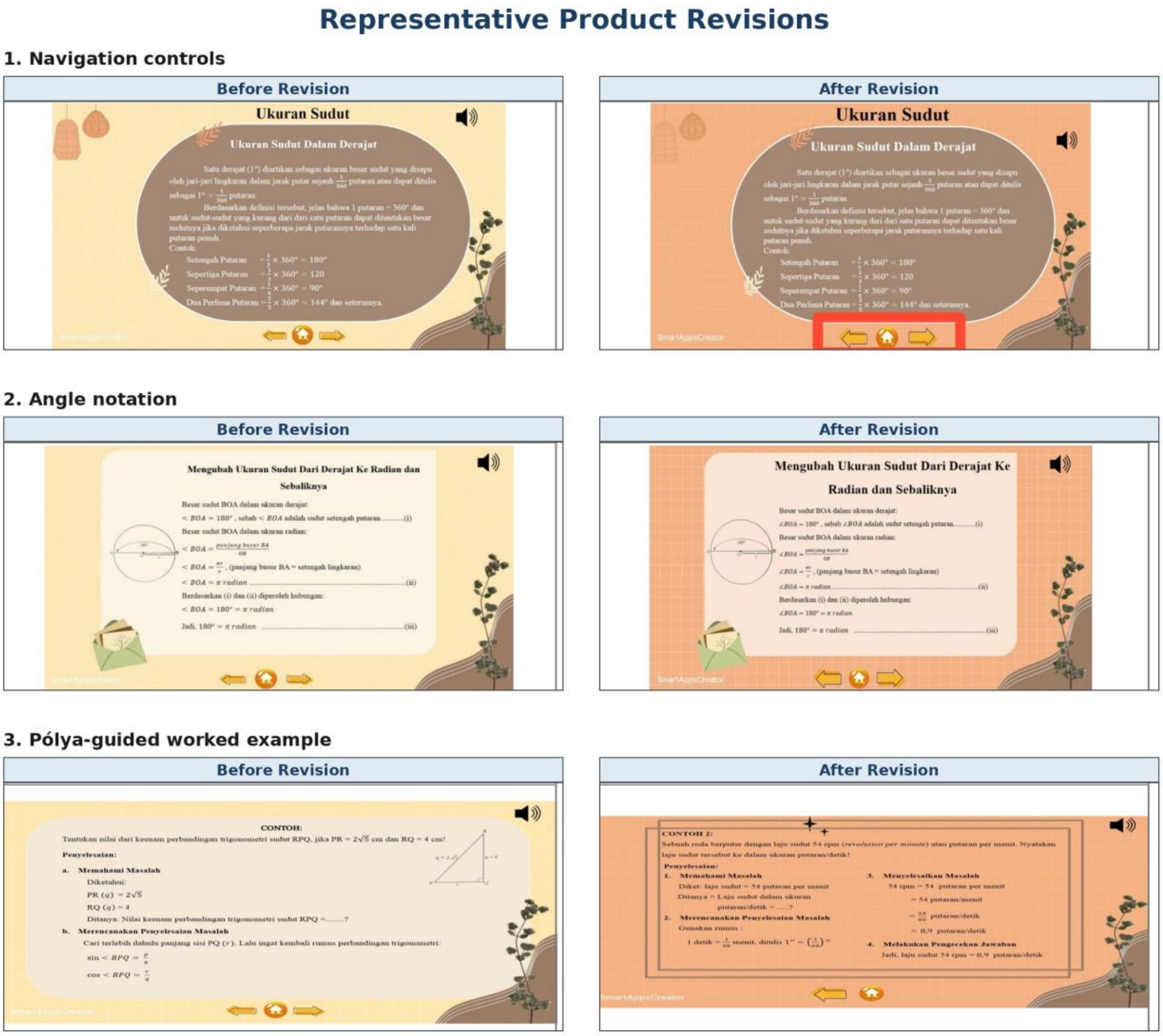

Figure 1. Representative before-and-after revisions to navigation, angle notation, and a Pólya-guided worked example.

Student response

The limited product trial involved 21 Grade 10 students and produced a complete 21 × 17 response matrix. Recalculation yielded an overall score of 1,413/1,785 (79.2%), classified as interesting and interpreted here as perceived attractiveness or acceptability. By aspect, content reached 76.0%, presentation 79.0%, language 83.8%, attractiveness 79.0%, and usefulness 81.6%. Language and usefulness were in the "very interesting" range, while content, presentation, and attractiveness were in the "interesting" range. Open-ended student comments were not collected, so no qualitative comments are reported.

Table 7. Student-response results by aspect

Aspect (items)	Score / maximum	Percentage / interpretation	Mean (median)	Range
Content (5)	399 / 525	76.0% / Interesting	3.80 (3.80)	3.20-4.80
Presentation (3)	249 / 315	79.0% / Interesting	3.95 (4.00)	3.00-4.67
Language (2)	176 / 210	83.8% / Very interesting	4.19 (4.00)	3.00-5.00
Attractiveness (4)	332 / 420	79.0% / Interesting	3.95 (4.00)	3.50-4.75
Usefulness (3)	257 / 315	81.6% / Very interesting	4.08 (4.00)	3.33-5.00
Overall (17)	1,413 / 1,785	79.2% / Interesting	3.96 (3.88)	3.65-4.65

Discussion

The e-module was developed in response to needs documented in the study school rather than as a technology-first intervention. In that school context, low trigonometry performance records, high reported difficulty, and reliance on static resources formed a coherent development rationale. Students' interest in digital materials may indicate a mismatch between existing presentation formats and some learners' preferences, but it does not by itself demonstrate that digital delivery will improve learning. This interpretation is consistent with evidence that digital tools are most productive when linked to identified learning problems and targeted pedagogy (Bano et al., 2018; Hillmayr et al., 2020). The empirical contribution of the present study is therefore contextual: its features were connected to documented needs in one school and one limited pilot.

The e-module's multimedia structure helps present abstract trigonometric concepts in interconnected verbal, symbolic, and visual representations. The division of the material into five subtopics, the provision of diagrams and examples, and clear navigation reduce the likelihood of students encountering too much material in a single display. According to multimedia learning theory, these features can facilitate cognitive processing when relevant words and images are presented in harmony and unnecessary elements are reduced (Mayer, 2020). Similar benefits were found in research on digital, interactive modules that systematically organize material and allow students to repeat learning at their own pace (Imansari & Sunaryantiningsih, 2017; Setiyani et al., 2020). This study extends these findings by demonstrating that Smart Apps Creator can integrate navigation, audio, games, explanations, and evaluation into trigonometry. However, the abundance of multimedia elements does not always indicate pedagogical quality, as inappropriate use of sound, color, and animation can actually disrupt student concentration. Therefore, a revision process is necessary to ensure the interface remains aligned with the mathematical meaning being learned.

The operational mapping of Pólya's stages gives the e-module a clearer instructional structure than a static electronic text. Students are prompted to identify known and unknown information, select a strategy, carry out the procedure, and review the result. Prior literature suggests that structured problem-solving materials can support the organization of mathematical reasoning (Arilaksmi et al., 2021), while problem-based learning studies emphasize meaningful tasks and reflection (Ramadanti et al., 2021; Siagian et al., 2019; Suparman et al., 2021). These literature findings should not be confused with evidence from the present study: no performance test was administered here. The present evidence is limited to the feasibility of operationalizing the four stages and expert/student perceptions of the resulting prototype.

The e-module contains learning games and immediate feedback, but this study did not isolate their effects or test whether either feature predicted student responses. Accordingly, any link between these features and product appeal remains a hypostudy for future research. Meta-analyses indicate that digital games can support motivation or achievement under some conditions, depending on instructional integration, duration, and game quality (Fadda et al., 2022; Tokac et al., 2019). In the present product, games functioned as supplementary practice and multiple-choice feedback provided immediate correctness information. These are design descriptions, not evidence that the features caused the 79.2% response score.

The validator results showed a numerical contrast between media feasibility (92.5% mean; 1.6-point gap) and content feasibility (84.4% mean; 16.2-point gap). The data therefore support the limited conclusion that the content judgments were less convergent than the media judgments. They do not demonstrate that interface quality developed faster than instructional quality. The recorded comments nevertheless show why technical appeal cannot substitute for mathematical accuracy: revisions were requested for notation, instructions, content sequencing, and problem-solving examples as well as for navigation and readability.

The aspect-level student responses provide a more precise interpretation than the overall 79.2% score alone. Language (83.8%) and usefulness (81.6%) were the strongest perceived dimensions, while content was lowest at 76.0%. This pattern suggests that students generally understood the wording and perceived practical value, but some content presentation still warranted refinement. Because the questionnaire measured perceptions rather than achievement, the result does not show improved trigonometric understanding or problem-solving ability.

The product can be situated within five related development studies. Those studies addressed digital mathematics products, Smart Apps Creator or Android delivery, and problem-solving orientations, but did not examine the same Grade 10 trigonometry product with an explicit screen-to-activity mapping of Pólya's four stages. The present study contributes an operational mapping of the four stages, a transparent set of expert-driven revisions, and separate reporting of media feasibility, content feasibility, and student perceptions. These contributions are descriptive and design-oriented; they do not establish superiority over other platforms or approaches.

A critical reading of the results also suggests several alternative explanations and contextual constraints. Students' positive ratings could be influenced by novelty effects, a desire to provide perceived good answers, or an interest in smartphone activities, rather than solely sustained engagement in trigonometric reasoning. The validation percentages are also based on only four validators and therefore do not represent all perspectives on curriculum, usability, and accessibility. The pilot was conducted in only one classroom and did not examine disparities in device ownership, the needs of students with disabilities, long-term use, or additional teacher workload. Furthermore, because the study did not conduct extensive operational testing and dissemination, the product's stability across devices and schools remains unknown. Educational design research views these limitations as a basis for further development, not a reason to consider the product a final, universal solution (Plomp & Nieveen, 2013). Thus, the appropriate conclusion is that the product has promising formative qualities, while its learning impact and scalability remain to be tested.

Implications

The research findings offer practical implications for mathematics teachers, schools, and digital learning resource developers. Teachers can use this product structure to organize mobile learning materials based on problem-solving stages, not just the order in which formulas are presented. Schools need to ensure that the implementation of digital modules is supported by the availability of devices, internet connections, technical support, and teacher readiness. Developers should prioritize readability, mathematical notation, material sequencing, and feedback quality before adding decorative multimedia elements. The research also suggests that product validation should involve media experts and mathematicians, as high technical quality does not guarantee high content quality. In classroom learning, e-modules are more appropriate as supplementary learning resources for guided and independent activities, not as a substitute for teacher-student interaction.

Research Contribution

This study contributes three design and reporting insights grounded in the study data. First, it documents how Pólya's four stages were translated into known/asked information, planning, calculation, and checking components in the revised examples and exercises. Second, it demonstrates why media and content ratings should be reported separately, because the two media ratings differed by 1.6 percentage points while the two content ratings differed by 16.2 points. Third, it separates expert feasibility judgments from student perceptions and does not treat positive responses as evidence of effectiveness. These insights can guide later development studies, but they require further testing in broader settings.

Limitations

The study implemented seven stages of the modified ten-step R&D procedure and was limited to one school, one Grade 10 class, one mathematics topic, two media experts, and two content experts. The study did not report the needs-questionnaire denominator, the class code or total enrollment, reasons for the difference between the 23 daily-test records and 21 pilot participants, prior device experience, or overlap among the preliminary and pilot groups. It also did not report psychometric reliability, post-revision expert revalidation, formal software version numbers, a comparison group, a pretest–posttest design, inferential analysis, or an effectiveness test. Constructed-response tasks still required paper, and compatibility across devices was not systematically tested.

Suggestions

Further research should conduct pilot tests in several schools with a more diverse student population and characteristics. A quasi-experimental or experimental design could be used to compare learning outcomes, problem-solving skills, and retention between students using the e-module and a relevant comparison group. The instrument should undergo pilot testing, construct validation, and reliability analysis. Subsequent versions should enhance accessibility, include digital descriptive answer features, allow for teacher monitoring, and test compatibility across various operating systems and device specifications. Research should also examine the role of teacher facilitation in influencing the relationship between e-module use and mathematics learning. Longitudinal evaluation is needed to determine whether initial interest can develop into sustained engagement and transferable problem-solving skills.

CONCLUSION

This study produced a Smart Apps Creator e-module that embeds Pólya's four stages across five Grade 10 trigonometry topics. Raw-score recalculation showed very feasible media ratings of 91.7% and 93.3% (mean 92.5%), content ratings of 92.5% and 76.3% (mean 84.4%), and a student response of 79.2%. Aspect-level student results ranged from 76.0% for content to 83.8% for language. These findings support the product's formative feasibility and perceived appeal in the study class. They do not establish effectiveness, because the study did not measure learning gains, problem-solving performance, retention, or comparison-group outcomes, and no post-revision revalidation was conducted.

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AUTHOR CONTRIBUTION STATEMENT

MN contributed to the research conceptualization, product development, instrument development, data collection and analysis, results visualization, and manuscript writing and revision. The author has read and approved the final version of the article.

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