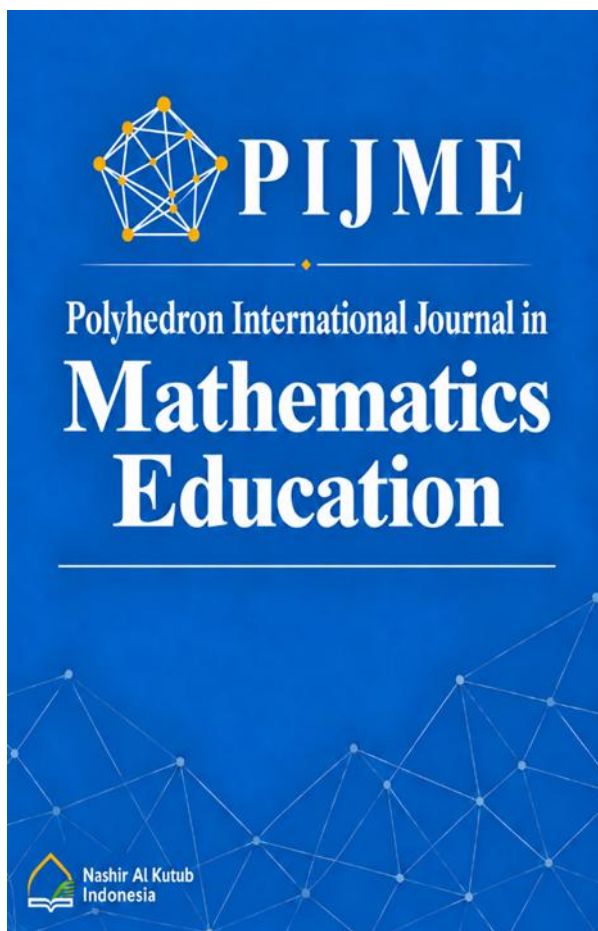




Inquiry under constraint: Fostering junior high school students' mathematical critical thinking and resilience through an offline guided inquiry e-module

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Abstract

Strengthening mathematical critical thinking and resilience is difficult in schools where digital access is restricted, such as Indonesian Islamic boarding schools (pesantren). This study developed an offline guided inquiry e-module on lines and angles for this setting and examined its validity, practicality, and preliminary effectiveness. Following the ADDIE model, a needs analysis at a pesantren-based junior high school informed a storyboard and a 29-page offline flipbook with three submodules organized around five inquiry stages and contexts from pesantren life. Three validators rated the e-module highly valid (Aiken's $V = 0.937$ for material and 0.924 for media), and their feedback led to minor revisions. In a three-meeting one-group pretest-posttest trial with all nine seventh-grade students, observed teacher implementation increased from 63.7% to 82.5% and student engagement from 59.2% to 78.9%, and the teacher (87.5%) and students (84.52%) rated the e-module very practical. Critical thinking scores rose significantly ($t(8) = 3.490$, $p = 0.008$, $dz = 1.163$; mean N-Gain = 0.360), and every student's resilience score increased (mean 49.33 to 58.22 of 80). Given the small sample and the absence of a comparison group, these results indicate preliminary within-group change rather than causal effects. The study offers a transferable design for offline, inquiry-based digital materials in technology-constrained schools.

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1. Introduction

Mathematics education carries a strategic responsibility in preparing people who can reason logically, think critically, and adapt to the demands of contemporary life. At the junior high school level, this responsibility can no longer be met through procedural drilling and computation alone. Students also need higher-order thinking

skills, particularly mathematical critical thinking, along with the affective disposition to keep working when a problem does not yield to their first attempted strategy. Indonesia's Merdeka Curriculum reflects this shift, placing deep learning, meaningful learning experiences, and twenty-first-century competencies such as critical reasoning, independence, and learning resilience at the center of instructional policy (Kemendikdasmen, 2025).

Mathematical critical thinking can be described as the ability to analyze, evaluate, and draw conclusions from mathematical information logically and systematically. It involves identifying possible solutions, evaluating and justifying results, and reflecting on one's own reasoning (Su et al., 2016), and it matters because mathematics is not only a computational tool but also a discipline for practicing reasoning and decision-making. Several studies have reported low levels of critical thinking in particular Indonesian junior high school samples, for example among eighth-grade students solving mathematical problems, who were weakest in evaluation, inference, and self-regulation (Basri et al., 2019), and among 403 junior high school students in Bali whose overall mastery of critical thinking skills remained below 60% (Redhana et al., 2026); in another junior high school, many students could not solve the problems presented and did not know which strategies to apply (Mellawaty et al., 2023). Indonesian students themselves have attributed weak mathematical critical thinking to difficulty remembering and understanding formulas, weak habits of seeking information, limited educational use of technology, and low internal motivation (Sulasti et al., 2026). These studies concern specific samples and cannot be generalized to all Indonesian students, so a local check was needed. A comparable pattern appeared in a preliminary assessment of nine seventh-grade students at SMP IT Rohmatul Ummah Kudus, who were given three essay-type Higher Order Thinking Skills (HOTS) items on numbers and fractions during the initial needs analysis. Only two students (22.22%) interpreted the problem accurately, three (33.33%) managed a simple analysis of the given information, one (11.11%) reached a logical and consistent conclusion, and the remaining three (33.33%) still worked from a misconception. Most students struggled to connect the information in a problem to a relevant mathematical concept, and many simply stopped once their first strategy failed to produce an answer right away, a pattern that points to an affective gap alongside the cognitive one, namely underdeveloped mathematical resilience.

Johnston-Wilder and Lee (2024) and Pulungan et al. (2022) describe mathematical resilience as students' capacity to persist, adapt, and maintain a positive attitude when they encounter difficulty, make mistakes, or fail while learning mathematics. Students who lack this capacity tend to give up quickly, avoid demanding tasks, and stop thinking as soon as their first strategy does not work (Johnston-Wilder & Lee, 2024; Kookan et al., 2016). A similar pattern was recorded in the preliminary observation, which was carried out during the critical thinking assessment described

above, on the same nine students, using an observation checklist of persistence behaviors (e.g., trying another strategy, checking an answer, stopping after one attempt) completed by the researcher and the mathematics teacher. The behaviors recorded for each student broadly lined up with how they performed on the reasoning task. Students who interpreted problems accurately or reached sound conclusions kept working when their first approach stalled, trying another route and reflecting on what had gone wrong, while students who were still working from a misconception tended to stop after one wrong attempt and made no further effort to revise it. In this small group, then, weak critical thinking and weak resilience tended to appear together, and this combination becomes even harder to address in a pesantren (Islamic boarding school) setting.

Part of the difficulty lies in the school context. The needs analysis preceded the design stage and combined four sources: the diagnostic test described above (all nine seventh-grade students), two observations of regular mathematics lessons using an observation checklist, semi-structured interviews with the principal, the mathematics teacher, and three students (the prompts asked about the materials in use, typical student difficulties, available devices, and rules on device use), and a document analysis of the printed textbook and worksheets used in class. These sources documented that SMP IT Rohmatul Ummah Kudus operates with limited formal instructional hours, does not allow students to use mobile phones outside class time, and has three laptops and one Interactive Flat Panel available for teaching. They also documented that the printed textbook and worksheets present content in a linear, mostly textual sequence; in the document analysis, the practice problems were predominantly formula-oriented rather than designed to ask students to assess a situation or compare solution paths, and in the observed lessons students mainly copied worked examples and rarely explained their reasoning. We interpret these findings to mean that the existing materials leave little room for exploration, reflection, or independent inquiry, and that students need a fair amount of resilience simply to keep learning under these constraints. Bećirović (2023) describes a similar limitation of conventional instructional materials more broadly, noting that they rarely combine technology with a pedagogy that supports active and reflective learning. This suggests that the school needs not simply new content but a different kind of learning material altogether, one built around challenging and supportive activities, which a well-designed e-module could plausibly provide.

An e-module, defined as instructional material organized to follow the curriculum and accessed through devices such as an Android phone, a computer, or a laptop (Alyusfitri et al., 2024), can support both classroom and independent learning (Setiyani et al., 2022) and offers a consistent, attractive layout, navigation buttons, and built-in exercises that allow students to study on their own (Alyusfitri et al., 2024). None of that, though, guarantees stronger critical thinking or resilience on its own. The format still

needs a learning approach capable of doing that work. Guided inquiry fits the purpose because it places students in the position of discovering a concept for themselves, working through problem formulation, hypothesis generation, data collection, and conclusion drawing under the teacher's direction rather than being handed the answer (Pedaste et al., 2015; Wijayanti et al., 2025). In an experimental study, Duran and Dökme (2016) found that guided inquiry-based activities significantly improved sixth-grade students' critical thinking skills, and a meta-analysis of 72 studies showed that guidance generally strengthens learning activities, performance success, and learning outcomes in inquiry learning (Lazonder & Harmsen, 2016).

A number of studies have already paired e-modules with inquiry-based approaches, and the results are encouraging. Dermawan et al. (2025) reported a significant gain in elementary students' critical thinking after using an interactive e-module, and Pramasdyahsari et al. (2023) found that a valid STEM project-based digital book on number patterns improved junior high school students' mathematical critical thinking. Beyond inquiry, Meri et al. (2026) showed that e-module-assisted contextual teaching and learning improved junior high school students' mathematical communication and learning motivation compared with conventional instruction. The two inquiry-oriented studies, however, were carried out in schools with reasonably good technological access, and neither treated mathematical resilience as an outcome to be developed alongside critical thinking, nor addressed a pesantren's restrictions on device use. More broadly, research on mathematical resilience has relied mainly on descriptive and correlational designs (Akkan & Horzum, 2024), so evidence from structured instructional interventions remains limited. This leaves a fairly specific gap: a guided inquiry-based e-module built for a technologically constrained, pesantren-based setting, aimed at strengthening both the cognitive and affective sides of mathematics learning at the same time.

Based on this background, this study aimed to (1) develop a guided inquiry-based e-module systematically designed to strengthen junior high school students' mathematical critical thinking and mathematical resilience, and (2) examine the feasibility of the developed e-module in terms of validity, practicality, and effectiveness in strengthening junior high school students' mathematical critical thinking and mathematical resilience. In this study, effectiveness was defined operationally for each outcome. For mathematical critical thinking, the e-module was considered effective if the posttest mean was significantly higher than the pretest mean (paired test, $\alpha = 0.05$) and the mean N-Gain reached at least the moderate category ($g \geq 0.3$). For mathematical resilience, effectiveness was judged descriptively as an increase in the mean total score and in each of the four dimensions from the first to the second measurement. Because a one-group design was used, these criteria document within-group change; they cannot isolate the effect of the e-module from testing, maturation, or ordinary instruction, and the findings are interpreted with this in mind.

2. Methods

This development study used the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation; Branch, 2009) to produce a guided inquiry-based e-module for seventh-grade mathematics and combined it with a one-group pretest-posttest design to document changes in students' mathematical critical thinking and mathematical resilience before and after using the e-module (Levine & Parkinson, 2014). ADDIE has also been used to develop digital learning media and e-modules for secondary school mathematics, including culturally contextual e-modules (Pakabu et al., 2024; Sari et al., 2025; Setiyani et al., 2022). The following subsections describe the research design, participants, data collection, and data analysis procedures used in this study.

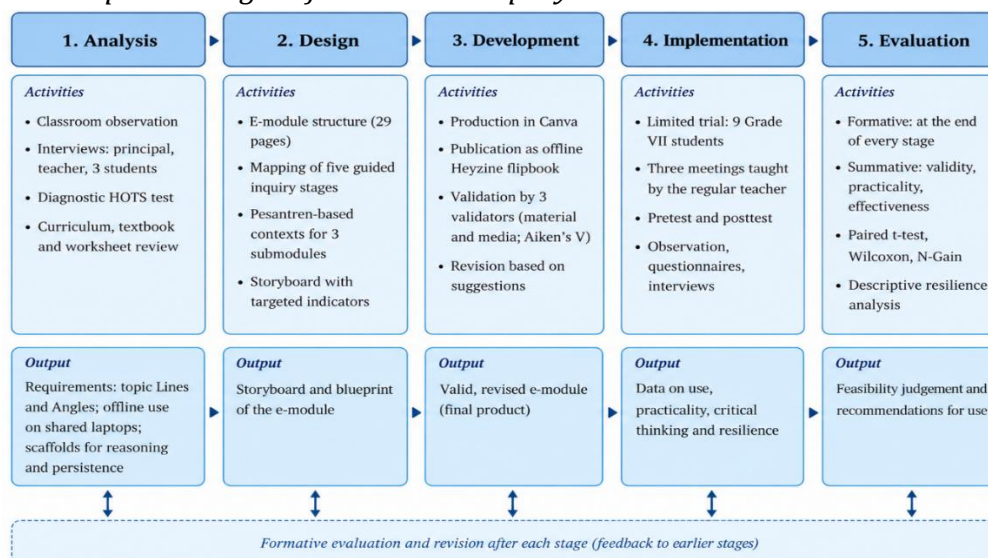
2.1 Research Design

ADDIE was chosen over other development models mainly for its flexibility. Its five stages, namely Analysis, Design, Development, Implementation, and Evaluation, allow the product to be refined continuously, using evaluation evidence gathered at every stage rather than only at the end (Branch, 2009); each stage produces an output that feeds the next, and the model's simple structure makes it adaptable to many learning environments (Spatioti et al., 2022). This suited the aim of the present study, since the primary goal was to produce a workable instructional product for a school with a fairly specific set of constraints. The Analysis stage examined student characteristics, the curriculum, the materials already in use, and classroom conditions in order to determine what the e-module needed to accomplish. In the Design stage, a storyboard (Mohd Yusoff & Halim, 2014) was used to lay out the e-module's structure, learning objectives, content, inquiry activities, and exercises, and to ensure that the guided inquiry stages aligned with the targeted indicators of critical thinking and resilience. The Development stage turned this design into a usable e-module, which was then validated by three validators who assessed both material and media aspects and revised accordingly. In the Implementation stage, the revised version was trialed with the research subjects to assess its practicality, while the Evaluation stage assessed the overall quality of the e-module, both throughout the process and at the conclusion of the trial. The stages were carried out sequentially: needs analysis informed the storyboard; design and development were followed by expert validation and revision; the limited trial comprised a pretest, three meetings, a posttest, and questionnaires; and the final evaluation informed further revision.

Figure 1 summarizes the five stages, the main activities and output of each stage, and the formative evaluation that linked them; the results of every stage are reported in Section 3.1.

Figure 1

ADDIE Development Stages of the Guided Inquiry-Based E-Module



Because the study population was very small and homogeneous, forming a separate control group was not feasible. Within-group change in mathematical critical thinking was therefore examined through a one-group pretest-posttest design, in which the same group of students was given a pretest (T1), followed by treatment in the form of e-module use (X), and then a posttest (T2). Changes in students' mathematical resilience were examined by comparing questionnaire scores obtained before and after the use of the e-module. Because there was no comparison group, this design cannot separate the contribution of the e-module from testing effects (familiarity with the pretest), maturation, or the influence of regular instruction during the same period (Shadish et al., 2002); the results are therefore interpreted as evidence of within-group change rather than as causal effects.

2.2 Participants

The participants of this study were nine seventh-grade students (eight male, one female) at SMP IT Rohmatul Ummah Kudus, a pesantren-based (Islamic boarding school) junior high school in Central Java, Indonesia. This entire cohort was involved as research subjects because it represented the only seventh-grade class at the school and provided the most direct and complete source of information on the practicality and effectiveness of the e-module under the school's actual, technologically constrained learning conditions, which included three laptops, one Interactive Flat Panel (IFP) display, and an internet connection dependent on teachers' personal mobile hotspots. Validity data were obtained from three validators, all mathematics teachers holding a master's degree and experienced in assessing instructional development products (two junior high school teachers and one vocational high school teacher), each of whom assessed both the material aspects and the media aspects of the e-module using two separate validation sheets. The needs analysis additionally

involved the principal, the seventh-grade mathematics teacher, and three students as interviewees, and the trial lessons were taught by the regular mathematics teacher while the first author observed. Prior to data collection, permission was obtained from the school principal and the class teacher, and informed consent was obtained from the students and their parents or guardians. Participants' identities and responses were kept confidential and reported only in aggregate or anonymized form throughout this study.

2.3 Data Collection

Data were collected through six instruments. First, two validation sheets were used to measure the validity of the e-module: a material validation sheet with 19 items covering five aspects (alignment with the Merdeka Curriculum, accuracy of content, integration with the guided inquiry model, feasibility of items and activities, and language readability) and a media validation sheet with 17 items covering four aspects (visual design, multimedia quality, navigation and interactivity, and technical quality). Each of the three validators completed both sheets, rating every item on a four-point Likert scale (4 = very good, no revision needed; 1 = poor, major revision needed). Second and third, separate practicality questionnaires were administered to the mathematics teacher and to the students, covering ease of use, clarity of content, engagement, learning benefit, and contextual suitability, using a four-point frequency Likert scale (4 = always; 1 = never).

Fourth, mathematical critical thinking was measured with parallel pretest and posttest forms on lines and angles. Each form consisted of one contextual story followed by four essay questions, one for each indicator synthesized from Facione (1990), Paul and Elder (2014), Halpern (2014), and Basri et al. (2019): interpretation (weight 20%), analysis (25%), evaluation (30%), and inference (25%). In the pretest story, a sports teacher stretches two parallel ropes (lines p and q) across the school field and a third rope (line t) that cuts both lines and forms a 65° angle, while two students disagree about whether co-interior angles sum to 90° or 180° . Students were asked to describe the positions of the three lines using precise terms, to determine the vertically opposite and supplementary angles of the 65° angle, to judge which student's claim was correct and solve for x in an expression for a corresponding angle, and to state a general conclusion about the angles formed when a transversal cuts two parallel lines. The posttest used an equivalent story about two parallel fence rails and a diagonal brace forming a 70° angle, with identical indicators, weights, difficulty, and rubric, so that memory of the pretest items was reduced. Each question was scored on a 0–4 rubric, giving a maximum raw score of 16 that was converted to a 0–100 scale. Fifth, a mathematical resilience questionnaire, developed from indicators of mathematical resilience described in the literature (Johnston-Wilder & Lee, 2024; Kookan et al., 2016), consisted of 20 statements, five for each of four indicators (perseverance and confidence, adaptive strategy, learning from failure, and curiosity

and reflection); the last statement of each indicator (items 5, 10, 15, and 20) was negatively worded. Items were rated on a four-point frequency scale (4 = always; 1 = never), negatively worded items were reverse-scored, and possible scores therefore ranged from 5 to 20 per dimension and from 20 to 80 in total. Sixth, two observation sheets were used during the trial: a 20-indicator sheet on the teacher's enactment of the five guided inquiry stages and a 19-indicator sheet on student engagement, both rated on a four-point scale (1 = not implemented; 4 = implemented very well). Semi-structured interview guides were used in the needs analysis with the principal, the mathematics teacher, and three students.

Before use, the instruments were reviewed by the same three validators and analyzed with Aiken's V. The coefficients were 0.827 for the resilience questionnaire, 0.852 for the student practicality questionnaire, 0.870 for the teacher practicality questionnaire, 0.870 for the material validation sheet, and 0.889 for the media validation sheet, all in the high category ($V > 0.8$). The critical thinking test obtained $V = 0.792$, at the upper end of the moderate category; following the validators' comments, its wording was revised for clarity and standard Indonesian before the pretest, and Aiken's V was not recomputed after this revision. The moderate content validity of the test is acknowledged as a limitation. The material and media ratings of the e-module reported in Tables 3 and 4 refer to the product itself and should not be interpreted as validity coefficients for the data collection instruments. Data collection followed the five ADDIE stages described in Section 2.1, and the results are reported stage by stage in Section 3.1.

2.4 Data Analysis

Validity data from the two validation sheets were analyzed using the Aiken's V coefficient (Retnawati, 2014, as cited in Kania et al., 2024): $V = \sum s / [n(c - 1)]$, where $s = r - l_0$; r is the score given by the validator; l_0 is the lowest score on the rating scale; n is the number of validators; and c is the number of rating categories. Aiken's V ranges from 0 to 1, with values below 0.4 indicating low validity, 0.4–0.8 indicating moderate validity, and above 0.8 indicating high validity (Retnawati, 2014, as cited in Kania et al., 2024). Because each validator completed both sheets, Aiken's V was computed separately for the material sheet and the media sheet ($n = 3$, $c = 4$), first for each item and then averaged per aspect.

Practicality data were analyzed descriptively using the formula $P = (S/M) \times 100\%$ (P = percentage of practicality, S = score obtained, M = maximum possible score), then classified as very practical ($82 \leq P \leq 100$), practical ($71 \leq P < 82$), fairly practical ($66 \leq P < 71$), less practical ($60 \leq P < 66$), or not practical ($P < 60$), adapted from Dahal et al. (2023). The bounds are written as continuous intervals so that percentages with decimals can be classified unambiguously.

Mathematical critical thinking scores were analyzed using a paired sample t-test to examine the mean within-group change, and the 95% confidence interval of the

mean difference was reported. The normality of the paired differences was checked with the Shapiro–Wilk test, which has shown comparatively high power among common normality tests in simulation studies (Yap & Sim, 2011), and, because the sample was very small, a Wilcoxon signed-rank test was run as a sensitivity analysis. For paired observations, Cohen's d_z was computed as the mean difference divided by the standard deviation of the paired differences, equivalently $t/\sqrt{n}$ (Lakens, 2013). Improvement relative to the available room for improvement was summarized using individual normalized gains: $g = (\text{posttest score} - \text{pretest score})/(\text{maximum score} - \text{pretest score})$, followed by their mean. Gains were classified as high ($g \geq 0.7$), moderate ($0.3 \leq g < 0.7$), or low ($g < 0.3$) (Hake, 1998).

Mathematical resilience was analyzed descriptively by comparing the mean and standard deviation of each dimension (possible range 5–20) and of the total score (20–80) before and after e-module use, together with the number of students whose total score increased and a Wilcoxon signed-rank test on the total scores. Students were classified as high ($x \geq \bar{x} + SD$), moderate ($\bar{x} - SD \leq x < \bar{x} + SD$), or low ($x < \bar{x} - SD$) on the basis of the sample mean and standard deviation; to keep the two occasions comparable, the cut-offs computed from the pretest mean and standard deviation were applied to both the pretest and the posttest scores. Observation scores were converted into percentages of the maximum possible score for each meeting. Observation and interview data were analyzed using data reduction, data display, and conclusion drawing (Miles & Huberman, 1994), with source and method triangulation used to examine the consistency of interpretations.

2.4 Ethical Clearance

The study followed ethical principles of informed consent, voluntary participation, confidentiality, and risk minimization. Permission was obtained from the principal and seventh-grade mathematics teacher of SMP IT Rohmatul Ummah Kudus. Parents or guardians provided informed consent, and students gave assent after receiving age-appropriate explanations of the study. Students could withdraw without any effect on their grades. The principal, teacher, and three validators also consented to participate. Participant data were coded, and only aggregated results and anonymized quotations are reported. Photographs in Figure 7 conceal students' identities and were approved for publication by parents or guardians. Raw data are stored on password-protected devices accessible only to the research team.

3. Results and Discussion

3.1 Results

The results are presented following the five stages of the ADDIE model, from the needs analysis to the final product and its classroom trial. Each stage produced an output that became the input for the next stage: the analysis produced design requirements, the design produced a storyboard, the development produced a

validated and revised e-module, the implementation produced data on its use in class, and the evaluation summarized its practicality and preliminary effectiveness.

3.1.1 Analysis Stage

The analysis stage was conducted in April 2026 through classroom observation, semi-structured interviews with the principal, the seventh-grade mathematics teacher, and three students, the diagnostic HOTS test described in the Introduction, and a review of the curriculum and of the printed textbook and worksheets. Curriculum analysis identified Lines and Angles (Garis dan Sudut) as a core topic of the Phase D learning outcomes of the Merdeka Curriculum for Grade VII, a topic in which Indonesian lower secondary students have been found to face both conceptual and psychological learning obstacles (Muhibban et al., 2023), and this topic was therefore selected for the e-module. Table 1 summarizes the main findings of the analysis and the design decisions derived from them.

Table 1

Needs Analysis Findings and Their Implications for the E-Module Design

Aspect	Main finding	Design implication
Curriculum	Lines and Angles is a core Phase D topic for Grade VII	Three submodules: lines, angles, and relationships between angles
Critical thinking	Students tended to memorize steps, found it hard to start analysis-type problems, and could rarely write down their reasoning; the teacher often had to give clues first	Guiding questions at every inquiry stage; answer spaces that ask for both an answer and a reason; hints placed in an optional “Need Help?” box
Mathematical resilience	Some students gave up early on long or unfamiliar problems and needed encouragement to keep trying	Non-routine challenges with a “My Strategy” box (first and alternative strategy), reflection prompts, and an affective reflection page
Learning materials	Printed textbook and worksheets presented content linearly, with routine, formula-oriented exercises	Contextual problems from pesantren life with exploration and reflection activities
Technology and school policy	No phones outside class; three laptops, one IFP, and internet only through the teacher’s hotspot; students were more enthusiastic with visuals and games	Offline flipbook on laptops, whole-class display on the IFP, printed answer sheets, and optional QR-linked games

The interviews illustrate these findings. The principal observed that many students “tend to memorize the steps without understanding the concept” and that

putting their reasoning into writing was the weakest aspect, while the mathematics teacher explained that students “need motivation so that they do not give up quickly, because their fighting spirit is sometimes still lacking”. Students described learning with the IFP as “more fun than looking at the printed book all the time”, but also said that they relied on printed worksheets in the dormitory because phones were not allowed (quotations translated from Indonesian). Taken together, the analysis indicated that the e-module had to scaffold reasoning without giving answers away, explicitly invite persistence and alternative strategies, and work offline on a few shared devices.

3.1.2 Design Stage

The design stage translated the analysis into the structure, inquiry flow, and storyboard of the e-module. The e-module was designed in Canva for publication as a Heyzine flipbook and comprises 29 pages: an opening section (pages 1–6: cover, foreword, table of contents, user guide, learning outcomes and objectives, and concept map), three submodules (pages 7–26), and a closing section (pages 27–29: Learning Talk Space, Mathematics Game Zone, and references). Each submodule follows the same five guided inquiry stages, presented with student-friendly feature names, as mapped in Table 2.

Table 2

Mapping of the Guided Inquiry Stages onto the E-Module Features

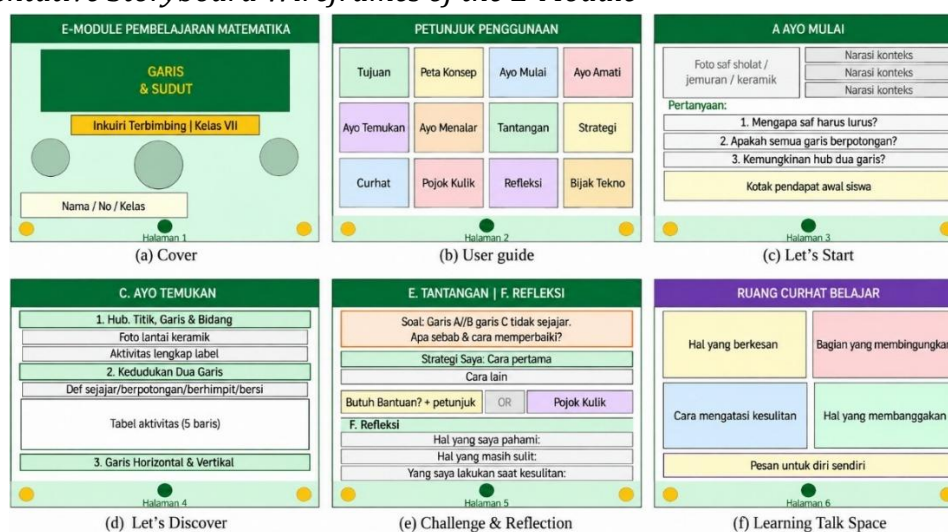
Inquiry stage	E-module feature	Pages (SM 1 / 2 / 3)	Pedagogical function
Orientation	Let's Start (Ayo Mulai): contextual problem	8 / 14 / 21	Elicits initial conjectures and activates prior knowledge through a pesantren context
Exploration	Let's Observe (Ayo Amati)	9 / 15 / 22	Trains systematic observation and identification of patterns
Investigation	Let's Discover (Ayo Temukan)	10–11 / 16–17 / 23–24	Guides concept construction through stepwise concrete activities
Elaboration	Let's Reason (Ayo Menalar)	11 / 18 / 25	Prompts students to articulate their understanding and argue mathematically
Reflection	Challenge & Reflection (Tantangan & Refleksi)	12 / 19 / 26	Non-routine problems, multiple strategies, graded scaffolding, and metacognitive reflection

Note. SM = submodule.

The three submodules use different contexts taken from daily life in the pesantren. Submodule 1 uses the arrangement of prayer rows (saf) to introduce lines and their relative positions, Submodule 2 uses a classroom door and an analog clock to introduce angles, and Submodule 3 uses road intersections in the pesantren to examine relationships between angles. Grounding mathematics tasks in students' religious and cultural life follows earlier designs based on Islamic values for madrasah students (Isnaini et al., 2023) and culturally contextual e-worksheets that were judged valid and practical for online mathematics learning (Sugiarni et al., 2026). The storyboard documented, for every page, a wireframe of the layout, the inquiry stage, the main content elements, and the critical thinking and resilience indicators targeted (Mohd Yusoff & Halim, 2014). Figure 2 shows representative wireframes. The Challenge and Reflection page, for example, was planned with a non-routine problem, a "My Strategy" box asking for a first and an alternative solution method, a "Need Help?" box with a QR link, an optional Curiosity Corner (Pojok Kulik) with extra problems, and three reflection prompts, targeting the inference and evaluation indicators as well as the resilience indicators of trying new strategies and learning from failure.

Figure 2

Representative Storyboard Wireframes of the E-Module



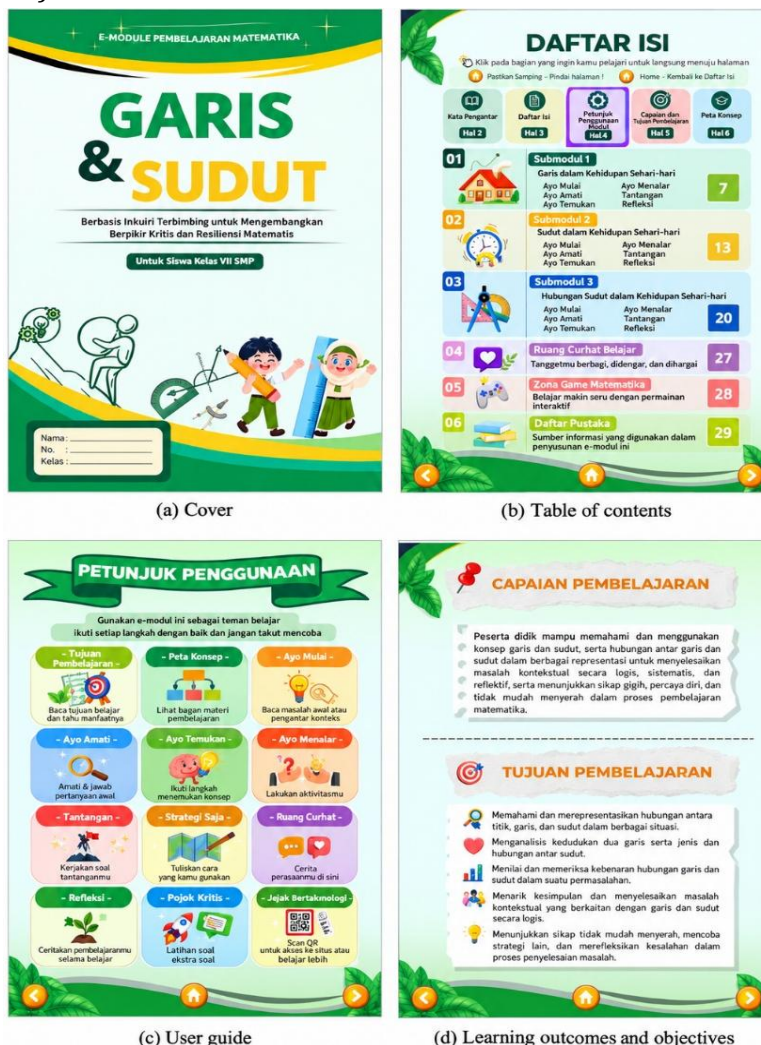
3.1.3 Development Stage

In the development stage, the storyboard was realized as a complete e-module in Canva using a consistent green-yellow palette, with a different theme color for each submodule (green, orange, and blue) to support navigation. The product was published with Heyzine Flipbook and downloaded as an offline package so that it could be opened in a web browser on the school laptops without an internet connection. In offline mode, page turning, the table of contents, internal navigation links, text, images, and embedded animations remained functional, whereas external links and online videos required a connection; these elements were replaced with static images or opened by

the teacher through a mobile hotspot. Figures 3–5 present the main parts of the product.

Figure 3

Opening Section of the E-Module



The opening section (Figure 3) builds the identity of the product with an illustration of santri, provides an interactive table of contents linked directly to each submodule, and explains every feature through twelve icon cards in the user guide, which gives students a mental map of the e-module before they begin. The learning outcomes page states the Phase D outcome and five objectives that combine cognitive targets (interpreting, analyzing, evaluating, and drawing conclusions about lines and angles) with an affective target (persisting, trying other strategies, and using mistakes to learn).

Figure 4

Guided Inquiry Pages of the Submodules

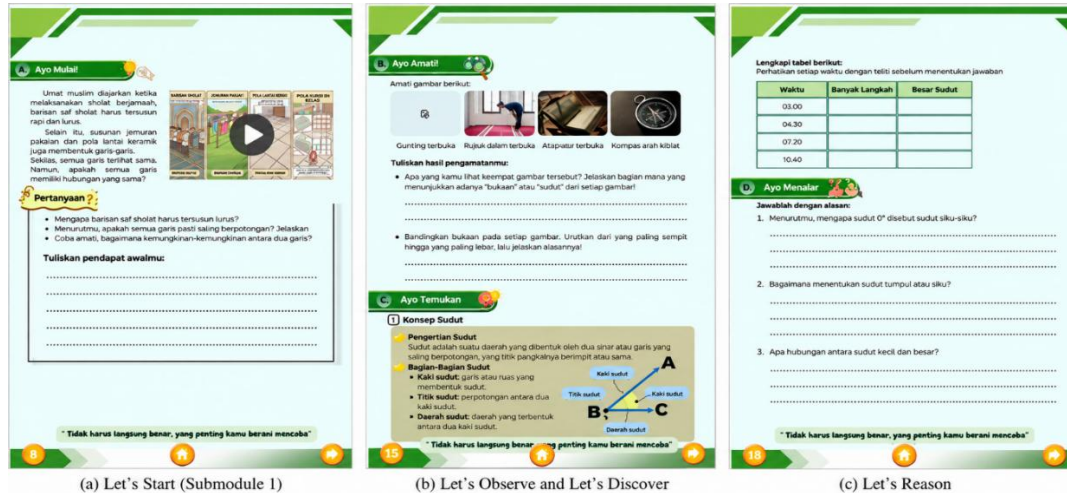
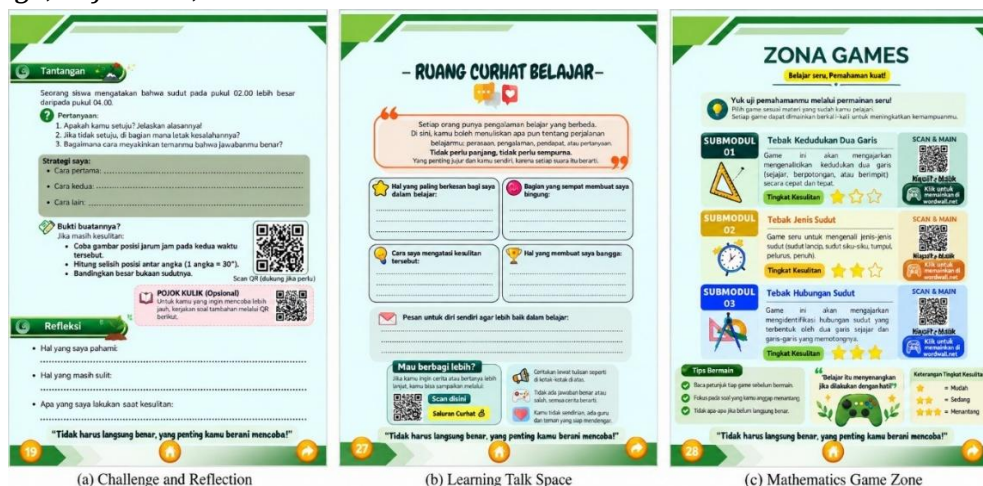


Figure 4 shows how the inquiry stages appear on the pages. In Let's Start (Figure 4a), students read a short narrative about straightening prayer rows, answer three trigger questions, and write an initial opinion before any concept is introduced. In Let's Observe (Figure 4b), they compare photographs of familiar objects, such as open scissors, bowing in prayer (ruku'), an open Qur'an, and a qibla compass, and explain which part of each object shows an angle; Let's Discover then introduces the definition and parts of an angle through a labelling task. The page in Figure 4c completes the discovery activity with a table relating clock times to the angle between the clock hands and then moves to Let's Reason, where students answer open questions that must be justified, such as why a 90° angle is called a right angle and how an angle can be determined without a measuring tool. Every page carries the motto "You don't have to be right straight away; what matters is that you dare to try", which was included to reinforce the resilience message.

Figure 5

Challenge, Reflection, and Enrichment Features



Each submodule closes with a Challenge and Reflection page (Figure 5a). In Submodule 2, for example, a santri claims that the angle between the clock hands at 02.00 is larger than at 04.00; students must agree or disagree with reasons, locate the error, and explain how they would convince a friend, writing a first strategy and an alternative strategy in the “My Strategy” box. A “Need Help?” box gives graded hints and a QR link to further support, the optional Curiosity Corner links to additional problems, and three prompts ask what students understood, what was still difficult, and what they did when they had difficulty. The Learning Talk Space (Figure 5b) provides four affective reflection boxes and a message-to-self box, with a QR form that is read only by the teacher, while the Mathematics Game Zone (Figure 5c) offers three QR-linked games of increasing difficulty on the position of two lines, types of angles, and angle relationships.

The initial product was then validated by the three validators using the material and media validation sheets. Table 3 presents the recapitulation of the material validation sheet, and Table 4 presents the recapitulation of the media validation sheet.

Table 3

Material Validity Rated by Three Validators — Aiken’s V by Aspect

Aspect	Items	Aiken’s V	Category
Alignment with the Merdeka Curriculum	3	0.889	High
Accuracy of mathematical content	4	0.917	High
Integration with the guided inquiry model	5	1.000	High
Feasibility of items and learning activities	4	0.917	High
Language and readability	3	0.963	High
Overall mean	—	0.937	High

Table 4

Media Validity Rated by Three Validators — Aiken’s V by Aspect

Aspect	Items	Aiken’s V	Category
Visual design quality	4	0.944	High
Multimedia quality	5	0.889	High
Navigation and interactivity	4	0.944	High
Technical quality	4	0.917	High
Overall mean	—	0.924	High

Every assessed aspect obtained an Aiken's V above 0.8, with an overall mean of 0.937 for the material aspects and 0.924 for the media aspects. Integration with the guided inquiry model reached full agreement ($V = 1.000$). At item level, two media items, video quality and offline accessibility, obtained a moderate coefficient ($V = 0.778$). All three validators concluded that the e-module was feasible to use without major revision, and their written suggestions were followed up as shown in Table 5 and Figure 6.

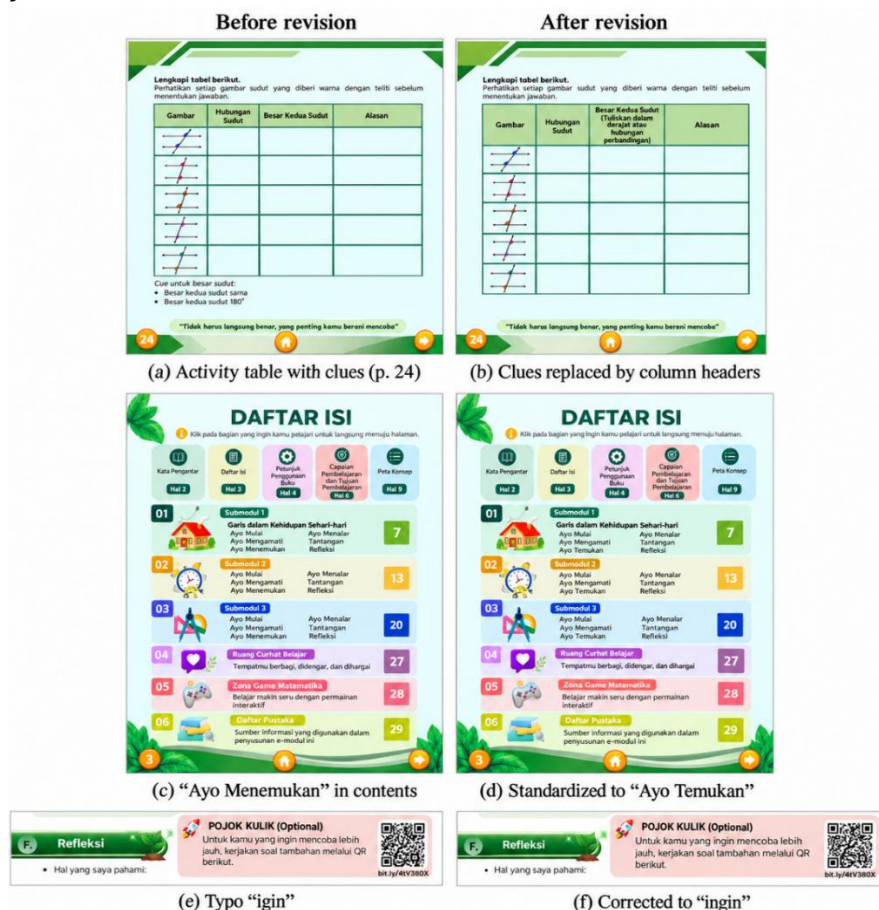
Table 5

Validator Suggestions and Follow-up Revisions

Validator	Suggestion	Follow-up revision
V1	In Let's Discover (Submodule 3, p. 24), the clues "the two angles are equal" and "the two angles sum to 180° " were printed directly below the activity table, so students could see the answer before trying	Clues removed; the column headers were made more descriptive so that students know the expected answer format without being given the answer
V1	Inconsistent feature name: "Ayo Menemukan" in the table of contents but "Ayo Temukan" on the content pages	Name standardized to "Ayo Temukan" throughout
V2	Typographical error "igin" (for "ingin", want) in the Curiosity Corner on pages 12, 19, and 26	Corrected on all three pages
V3	Add practice problems for each topic	No change needed; each submodule already links to extra problems through the Curiosity Corner QR code, and the Game Zone provides practice games

Figure 6

Examples of Revisions Based on Validator Feedback



The most substantive revision concerned the activity table in Submodule 3 (Figure 6a-b). Printing the clues below the table would have turned the investigation into a matching exercise, so the clues were removed and the column headers were rewritten to indicate the expected form of the answer (e.g., "size of both angles, written in degrees or as a relationship"). The remaining revisions improved consistency and accuracy (Figure 6c-f). The revised e-module, consisting of 29 pages in three submodules, was the product used in the implementation stage.

3.1.4 Implementation Stage

The revised e-module was implemented in three meetings of two lesson periods each in the seventh-grade class, with the regular mathematics teacher conducting the lessons and the first author observing. Although the e-module was designed to be worked through individually, only three laptops were available for nine students, so the students shared one laptop in groups of three solely to gain device access, not as part of a collaborative learning design. The teacher displayed the e-module on the IFP for whole-class orientation and discussion, and students wrote their answers on

printed answer sheets that mirrored the e-module pages. Figure 7 documents the classroom process.

Figure 7

Implementation of the E-Module in the Classroom



The first meeting was a period of adaptation. The teacher introduced the e-module on the IFP before the students opened it on the laptops, and the students responded enthusiastically to its visual appearance, which differed from their usual worksheets. However, uneven access to the shared laptops slowed the transitions between stages, so the elaboration and reflection stages were shortened. In the second meeting, the teacher organized laptop turns more efficiently and began to use Socratic questioning in the exploration stage; class discussion became livelier, and two groups, instead of one, presented their findings. In the third meeting, students more often tried a problem themselves or discussed it briefly with their group before calling the teacher, two groups tried an alternative strategy successfully, and some students found solution paths that differed slightly from the main path of the e-module. Table 6 summarizes the observation results.

Table 6

Teacher Implementation and Student Engagement Across the Three Meetings

Meeting	Observation target	Score	Maximum	%	Category
1	Teacher implementation	51	80	63.7	Fair
	Student engagement	45	76	59.2	Fair
2	Teacher implementation	63	80	78.8	Good

Meeting	Observation target	Score	Maximum	%	Category
3	Student engagement	58	76	76.3	Good
	Teacher implementation	66	80	82.5	Good
	Student engagement	60	76	78.9	Good

Note. Teacher implementation was rated on 20 indicators and student engagement on 19 indicators, each on a 1–4 scale.

Both observation targets increased consistently from the first to the third meeting. Teacher implementation rose from the fair category (63.7%) to the good category (82.5%), and student engagement from fair (59.2%) to good (78.9%). The student indicators most closely linked to the design of the e-module changed in the same direction: not giving up when formulating a problem, trying another strategy when the first one failed, and using the reflection features of the e-module each rose from 2 in the first meeting to 3 in the second and third meetings, and showing a positive attitude toward mistakes as part of learning reached 4 in the third meeting. After the third meeting, the teacher and the students completed the practicality questionnaires (Table 7).

Table 7

Recapitulation of E-Module Practicality — Teacher and Student Questionnaires

Respondent	Aspect	P (%)	Category
Teacher (n = 1)	Ease of use	100.00	Very practical
	Clarity of content	91.67	Very practical
	Support for student engagement	75.00	Practical
	Benefit for the teacher	83.33	Very practical
	Suitability to the pesantren context	87.50	Very practical
	Overall	87.50	Very practical
Students (n = 9)	Ease of use	87.04	Very practical
	Clarity of content	82.41	Very practical
	Visual appearance	89.81	Very practical
	Learning benefit	75.93	Practical
	Comfort and interest	88.89	Very practical
	Overall	84.52	Very practical

The teacher and students rated the e-module in the very practical category, at 87.5% and 84.52%, respectively. The teacher gave the highest rating to ease of use (100%) and the lowest to support for student engagement (75%), which is consistent with the observation that some students needed time to engage fully in the inquiry stages during the first meeting. Among the students, visual appearance (89.81%) and comfort and interest (88.89%) were rated highest, and learning benefit (75.93%) lowest.

3.1.5 Evaluation Stage

Evaluation was carried out formatively throughout the development process, through the needs analysis, the storyboard, the expert validation, and the revision, and summatively after the trial, using the critical thinking test, the resilience questionnaire, the practicality questionnaires, and the observation data. Mathematical critical thinking was assessed using pretest and posttest essay scores with a maximum of 100. The mean increased from 29.58 (SD = 20.68) to 56.53 (SD = 21.75), a mean within-group gain of 26.95 points. The Shapiro–Wilk test on the paired differences indicated no departure from normality ($W = 0.952$, $p = 0.714$), so the paired sample t-test was used; its results, the effect size, and the normalized gain are summarized in Table 8.

Table 8

Paired Sample t-Test, Effect Size, and N-Gain Results for Mathematical Critical Thinking

Statistic	Value	Decision/Category
Pretest M (SD)	29.58 (20.68)	—
Posttest M (SD)	56.53 (21.75)	—
Shapiro–Wilk, paired differences	$W = 0.952$, $p = 0.714$	Normal
t (df = 8)	3.490 (t-table = 2.306)	H0 rejected
p-value	0.008	Significant ($\alpha = 0.05$)
Mean difference (95% CI)	26.95 [9.14, 44.76]	CI excludes 0
Wilcoxon signed-rank (sensitivity)	$W = 2$, exact $p = 0.012$	Significant ($\alpha = 0.05$)
Cohen's dz (paired)	1.163	Large effect
Mean N-Gain	0.360	Moderate
Minimum mastery criterion (KKM $\geq$ 75) reached	Pretest 0%; Posttest 33.3%	—

The paired sample t-test yielded a statistically significant within-group increase ($t(8) = 3.490$, $p = 0.008 < 0.05$; mean difference = 26.95 points, 95% CI [9.14, 44.76]), and the Wilcoxon signed-rank test led to the same conclusion ($W = 2$, exact $p = 0.012$). The effect size, computed as Cohen's dz for paired observations ($dz = t/\sqrt{n} = 1.163$), was large. Eight of the nine students improved; the only student whose score decreased (–13.8 points) was reported to be unwell on the day of the posttest. The mean N-Gain

of 0.360 fell in the moderate category; two students (22.2%) reached the high N-Gain category, two (22.2%) the moderate category, and five (55.6%) the low category. These two indices answer different questions. Cohen's d_z expresses the mean change relative to the variability of individual changes, whereas N-Gain expresses each student's change relative to the room available for improvement; because the pretest mean was low (29.58 of 100), a student who gained about 20 points still obtained $g < 0.3$. The N-Gain distribution therefore shows that the size of the gains was uneven and that substantial gains were concentrated in four students. No student reached the minimum mastery criterion ($KKM \geq 75$) on the pretest, compared with three students (33.3%) on the posttest. Mathematical resilience was measured before and after e-module use across four dimensions, as shown in Table 9.

Table 9

Comparison of Mathematical Resilience Scores Before and After E-Module Use ($n = 9$; possible range 5–20 per dimension and 20–80 in total)

Dimension	Pretest M (SD)	Posttest M (SD)	ΔM
Perseverance and confidence	12.89 (3.22)	14.56 (2.07)	+1.67
Adaptive strategy	11.89 (3.62)	13.78 (2.73)	+1.89
Learning from failure	11.67 (3.08)	15.00 (2.24)	+3.33
Curiosity and reflection	12.89 (3.62)	14.89 (2.67)	+2.00
Total score	49.33 (12.28)	58.22 (8.39)	+8.89

The mean total mathematical resilience score increased from 49.33 (SD = 12.28) to 58.22 (SD = 8.39) out of a possible 80, a gain of 8.89 points, and the total score of every student increased (individual gains from 2 to 19 points; Wilcoxon signed-rank $W = 0$, exact $p = 0.004$). Mean scores increased in all four dimensions: perseverance and confidence (+1.67), adaptive strategy (+1.89), learning from failure (+3.33), and curiosity and reflection (+2.00), with learning from failure showing the largest increase. Using cut-offs derived from the pretest distribution (low < 37.06 ; high ≥ 61.61), two students were classified as low, five as moderate, and two as high before the trial; after the trial, both low-scoring students had moved into the moderate category, and the high group was unchanged. Because the questionnaire was self-reported by nine students over a short trial, these results are interpreted as preliminary descriptive evidence of change. Beyond these outcome data, the evaluation identified two conditions for the future use of the e-module: more time for the elaboration and reflection stages and enough devices for students to work through the e-module individually, as intended.

3.2 Discussion

The development results show how each ADDIE stage shaped the final product. The analysis stage did more than confirm that new material was needed; it fixed the

main design constraints, namely offline access on a few shared laptops, a ban on phones outside class, and students who could often reach an answer but could not yet write down their reasoning or persist after a first failure. These constraints account for three features of the final product: an offline flipbook supported by printed answer sheets, answer spaces that ask for a reason as well as an answer, and the explicit first-strategy and alternative-strategy structure of the challenge pages. The validators' suggestions also strengthened the inquiry character of the product. Removing the clues from the Let's Discover table, for example, preserved the opportunity for students to find the angle relationships themselves, consistent with the view that guided inquiry directs students through questions without handing them the answer (Lazonder & Harmsen, 2016). The implementation stage, in turn, showed that the e-module depended on how it was enacted: student engagement rose together with the teacher's use of Socratic questioning and a better-organized rotation of devices, which suggests that the product works best with active teacher facilitation rather than as a stand-alone resource. This interpretation is consistent with evidence that guided teaching, technology integration, and learner engagement each contribute significantly to students' mathematical problem-solving ability (Gyenyn et al., 2026).

The high validity scores on both validation sheets suggest the e-module met the curricular, content accuracy, and design standards expected of a usable instructional product. What stands out most is the perfect agreement ($V = 1.000$) on integration with the guided inquiry model: all three validators judged the five inquiry stages to be presented completely and consistently. This matters because, as the synthesis of inquiry phases by Pedaste et al. (2015) indicates, inquiry works when its phases form a coherent cycle that leaves students room to discover concepts on their own rather than being told them directly. Together, these results answer the validity component of the study's second objective.

Teacher and student practicality ratings landed close together, at 87.5% and 84.52%, respectively, both falling in the very practical category. This suggests that, within the three trial meetings, the e-module was usable in practice despite the school's limited technology, including when three students shared one laptop. The teacher's perfect score on ease of use likely traces back to the Canva- and Heyzine-based interface, which is worth noting given that pesantren-based schools often cannot count on their teachers having a strong technology background to begin with. The aspect that students rated lowest, learning benefit (75.93%), still fell within the practical range; one possible explanation is that students used the e-module for only three meetings, which may be too short for them to perceive clear benefits, particularly for affective outcomes such as resilience that tend to develop gradually. Johnston-Wilder and Lee (2024) make a similar point, describing mathematical resilience as something that builds gradually through repeated, supportive learning experiences rather than all at once.

The improvement in mathematical critical thinking was both statistically significant ($t(8) = 3.490$, $p = 0.008$) and, given a Cohen's d_z of 1.163, large in standardized terms, which addresses the effectiveness component of the study's second objective as it was operationalized here. Because the design had no comparison group, however, this increase cannot be attributed to the e-module alone; familiarity with the test format, maturation, ordinary instruction, and the novelty of a digital module may also have contributed. That the mean N-Gain landed in the moderate range rather than the high range is not especially surprising, given that the trial ran for only three meetings under conditions that remained fairly limited technically. This pattern broadly aligns with what Arifin et al. (2025) reported in their meta-analysis of inquiry-based learning, which found a large average effect on critical thinking ($SMD = 1.27$) that nonetheless varies with context and intervention duration. It also echoes Wicaksana et al. (2020), who found that incorporating critical thinking elements into a module contributed substantially to academic achievement. The investigation and elaboration stages were designed to prompt students to justify their answers and consider alternative solution strategies, aligning with the analysis, evaluation, and inference indicators described by Facione (1990). This design alignment offers a plausible pedagogical explanation for the observed mean increase, but the available reporting does not establish these processes as mechanisms of change.

Mathematical resilience also showed a descriptive increase, with a total score gain of 8.89 points spread across all four dimensions, an increase for every student, and the largest increase in learning from failure. This pattern is consistent with the possibility that a guided inquiry-based e-module can support the affective side of mathematics learning and not only the cognitive side, and it parallels Secadron Jr and Tan (2023), who reported that a Process-Oriented Guided Inquiry Learning e-module improved students' perseverance when facing difficulty. The observation data offer some convergent support: the indicators of trying another strategy, using the reflection features, and accepting mistakes as part of learning rose over the three meetings. These observations were, however, recorded at class level by the researcher, and the resilience scores were self-reported by nine students after only three meetings, so together they indicate a direction of change rather than an established effect. Taken together, the validity, practicality, and within-group change findings suggest that, in this pesantren school, the e-module was usable and was accompanied by improvements in students' critical thinking and self-reported resilience. Whether such an e-module can help schools with limited technological infrastructure meet the national curriculum's push toward deep learning and critical, creative, and reflective thinking (BSKAP, 2025) remains to be tested in larger studies with comparison groups.

3.3 Limitations

This study has several limitations that should be considered when interpreting its findings. First, the one-group pretest-posttest design without a comparison group

cannot rule out alternative explanations for the observed changes, such as familiarity with the test format, maturation, regular instruction, or the novelty of using a digital module (Shadish et al., 2002). Second, the sample was very small and homogeneous (nine students, eight of them male, from the only seventh-grade class of a single pesantren-based school), which limits statistical power and the generalizability of the findings; future studies should involve larger and more varied samples across several schools, ideally with a comparison group. Third, implementation was limited to three meetings and no delayed posttest was administered, so the durability of the gains is unknown; a longer implementation would also allow the elaboration and reflection stages to develop more fully. Fourth, the lessons were taught by a single teacher and observed by the first author, so teacher effects and observer expectations cannot be separated from the effect of the material itself. Fifth, mathematical resilience was measured mainly through a self-report questionnaire; future research should complement it with systematic behavioral observation of individual students. Finally, the critical thinking test reached only a moderate content validity coefficient ($V = 0.792$), and students shared laptops in groups of three, although the e-module was designed for individual use, which may have influenced individual engagement with the inquiry activities.

4. Conclusion

This study developed a guided inquiry-based e-module on lines and angles intended to strengthen junior high school students' mathematical critical thinking and mathematical resilience. The ADDIE process moved from a needs analysis that identified the school's offline, shared-device conditions and students' difficulties in writing their reasoning and persisting after failure, through a storyboard, to a 29-page offline flipbook with three submodules that follow five inquiry stages (orientation, exploration, investigation, elaboration, and reflection) around contexts drawn from pesantren life. The three validators rated it highly valid on both the material and the media aspects, and their suggestions led to minor revisions that preserved the discovery character of the activities. During the three-meeting trial, observed teacher implementation and student engagement improved from the fair to the good category, and the teacher and students rated the e-module very practical despite the school's limited technology. Students' mathematical critical thinking increased significantly, with a large standardized effect and a moderate mean N-Gain, although gains were uneven across students, and self-reported mathematical resilience increased for every student and in all four dimensions. Because these results come from nine students in one school over three meetings without a comparison group, they should be read as preliminary evidence of feasibility and within-group change rather than as proof of causal effectiveness. Within these limits, the e-module appears to be a workable option

for schools with limited technological access, including pesantren-based schools, and merits further testing in controlled studies with larger samples.

Statements and Declarations

Funding:

This research was carried out independently by the authors without external funding.

Competing Interests:

The authors declare no conflict of interest.

Research Permission:

Permission to conduct the study was obtained from the principal and the class teacher of SMP IT Rohmatul Ummah Kudus, Central Java, Indonesia.

Informed Consent:

Informed consent was obtained from the students and their parents or guardians. Participants' identities and responses were kept confidential and reported only in aggregate or anonymized form.

Data Availability:

The data supporting the findings of this study are available from the corresponding author upon reasonable request, subject to participant confidentiality.

Author Contributions:

Heti Handayani: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing.

Yumiati: Writing – review & editing, Supervision, Validation.

Nia Jusniani: Writing – review & editing, Formal analysis, Methodology.

Declaration of Generative AI Use:

ChatGPT (OpenAI) was used to assist with language editing, revision of manuscript wording, and identification of incomplete reporting. It was not used to generate research data, statistical results, or participant quotations.

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