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DEVELOPMENT OF SCRATCH-BASED E-MODULES ON VALUABLE COMPARISON MATERIALS TO IMPROVE THE UNDERSTANDING OF MATHEMATICS CONCEPTS OF GRADE VIII JUNIOR HIGH SCHOOL STUDENTS

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ABSTRACT
This study aimed to develop a *Scratch*-based e-module on direct proportion for eighth-grade junior high school students that meets the criteria of validity, practicality, and effectiveness. The developed e-module integrates *Project-Based Learning* (PjBL) and constructionism principles through interactive activities and visual programming projects designed to support students' mathematical conceptual understanding. This research employed a development research approach based on the Plomp model, which consists of three phases: *preliminary research*, *prototyping phase*, and *assessment phase*. The research subjects consisted of 10 Grade VIII B students in the initial trial, 27 Grade VIII B students in the limited trial, and 38 Grade VIII A students in the product implementation phase. Data were collected through validation sheets, student response questionnaires, and mathematical conceptual understanding tests. The results showed that the developed e-module achieved an average validity score of 3.43, categorized as very valid. The practicality score obtained was 3.83 in the limited trial, categorized as very practical. The implementation results indicated that the average score of students' mathematical conceptual understanding increased significantly from 42.50 on the pre-test to 81.32 on the post-test. The results of the *Paired Samples t-Test* revealed that the improvement was statistically significant. Furthermore, the effect size analysis using Cohen's *d* yielded a value of 3.45, indicating a very large effect of the e-module on improving students' mathematical conceptual understanding. Based on these findings, it can be concluded that the *Scratch*-based e-module on direct proportion fulfills the criteria of being valid, practical, and effective, making it highly suitable for use as a digital learning resource to support meaningful mathematics learning in junior high schools..

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INTRODUCTION

Mathematics education plays a fundamental role in developing students' logical reasoning, analytical thinking, and problem-solving skills, which are essential for navigating the complexities of the modern world. Within the mathematics curriculum, proportional reasoning is recognized as a cornerstone concept that bridges elementary arithmetic to more advanced mathematical domains such as algebra, geometry, and trigonometry. According to Lamon (2012), the ability to reason proportionally is considered one of the highest levels of mathematical reasoning that students must master during their junior high school years, as it serves as the foundational bedrock for understanding complex functional relationships. Furthermore, Van de Walle et al. (2013) emphasize that a deep understanding of proportionality cannot be achieved merely through the rote memorization of formulas; rather, it requires relational understanding that connects abstract mathematical concepts to real-world situations, enabling students to recognize patterns and relationships between varying quantities in diverse contexts.

At the core of mathematics education is the development of conceptual understanding, which goes beyond the mere ability to perform procedural calculations. Susanto (2016) defines conceptual understanding as the comprehensive ability of students to interpret, explain, and provide examples of mathematical ideas, allowing them to construct clear mental models of both concrete objects and abstract concepts. This aligns with the perspective of Nurafni (2018), who asserts that true conceptual understanding occurs when students are capable of discovering and proving mathematical concepts independently without relying on memorization, thereby enabling them to apply these concepts flexibly and accurately in various problem-solving scenarios. When students possess a strong conceptual foundation, they are better equipped to tackle unfamiliar mathematical challenges because they understand the underlying principles rather than just the sequential steps required to reach an answer.

Despite the critical importance of conceptual understanding, empirical evidence indicates that students' mastery of direct proportion remains significantly low, presenting a persistent challenge in mathematics education. Suryanto (2019) highlights that one of the primary reasons students struggle with proportion-related problems is their fundamental lack of conceptual understanding, which prevents them from distinguishing between direct and inverse proportions in varied contexts. This difficulty is further corroborated by Rahmawati (2020), whose research revealed that approximately 55% of junior high school students experience severe difficulties in solving word problems related to direct proportion, primarily because they have a weak conceptual grasp and struggle to connect abstract mathematical concepts with contextual, real-life scenarios presented in narrative forms.

The root cause of these persistent learning difficulties is often attributed to conventional, monotonous instructional methods that fail to stimulate active cognitive engagement. Aunurrahman (2014) explains that learning processes devoid of instructional variation tend to cause students to lose interest and motivation, as they do not receive adequate stimulation to participate actively in constructing their own knowledge. Consequently, the material is only understood superficially without the development of deep conceptual mastery. In line with this, Rizky and Surya (2017) found that a minimal variation in teaching methods is a primary factor that hinders students from building accurate mathematical concepts, noting that students who merely receive one-way explanations from teachers without active involvement experience significantly greater difficulties in understanding direct proportion compared to those engaged in interactive learning environments.

To overcome the abstract nature of mathematical concepts, the integration of appropriate instructional media is imperative to bridge the gap between concrete experiences and abstract reasoning. Daryanto (2013) states that the use of appropriate and engaging learning media can significantly improve students' conceptual understanding because good media is capable of presenting abstract concepts in a more concrete and easily digestible format. This is supported by Arsyad (2014), who argues that technology-based learning media offers the distinct advantage of presenting material visually and interactively, which can be repeated according to the students' individual needs, thereby providing every student with the opportunity to learn at their own pace and according to their unique learning styles.

From a pedagogical standpoint, Project-Based Learning (PjBL) offers a robust framework for fostering active engagement and contextual understanding through the creation of tangible products. Kazu et al. (2022) demonstrated through experimental research that students in classes implementing PjBL achieved significantly higher conceptual understanding scores and exhibited greater active engagement during the learning process compared to those in

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conventional classrooms. This approach is deeply rooted in authentic learning theories, as explained by Darmawati and Mustadi (2023), who note that PjBL provides opportunities for students to explore and develop their multiple intelligences by engaging in carefully designed projects that reflect real-world challenges, thereby allowing them to connect their academic knowledge with practical, everyday contexts.

The implementation of PjBL in mathematics is strongly underpinned by the theory of constructionism, which posits that learning is most effective when students are actively involved in constructing meaningful, shareable artifacts. Edith et al. (2009) elaborate that constructionism provides an optimal learning environment when it features activities directed toward meaningful learning, presents real challenges, and provides tools that allow students to express and construct their knowledge actively. This philosophy is succinctly captured by Papert and Harel (1991), who define constructionism as "learning-by-making," asserting that knowledge is most effectively built when students are directly involved in creating something that can be seen, tested, and shared with others, thereby transforming them from passive consumers of information into active designers of their own cognitive frameworks.

In the context of digital constructionism, Scratch emerges as a highly effective visual programming platform that allows students to manipulate mathematical objects dynamically and intuitively. Surur et al. (2023) proved through quasi-experimental research that mathematics learning integrated with Scratch-based activities significantly improves students' conceptual understanding, as students are required to create animations and simulations that directly reflect the mathematical concepts they are learning. The unique affordances of Scratch are highlighted by Resnick et al. (2009), who identify its core principles as being more tinkerable, more meaningful, and more social than traditional programming languages, allowing students to freely experiment, test hypotheses, and visually represent abstract mathematical relationships without being hindered by complex syntax errors.

To deliver this constructionist, Scratch-based learning experience systematically, the development of an interactive e-module serves as an ideal digital medium that accommodates diverse learning needs and promotes autonomy. Tarigan et al. (2021) found that the use of interactive digital modules significantly increases student activity and learning autonomy compared to conventional methods, as e-modules can integrate multimedia elements such as simulations, videos, and interactive exercises that cater to various learning styles. Furthermore, Sulistyowati and Setyoningsih (2023) affirm that the utilization of technology in mathematics learning not only increases accessibility but also positively impacts students' learning interest, creating a more inclusive and innovative learning environment where students can access structured, self-instructional materials anytime and anywhere.

Despite the extensive research supporting the individual components of PjBL, Scratch programming, and interactive e-modules, there remains a significant gap in the literature regarding their integrated application specifically for teaching direct proportion. While Mira et al. (2021) demonstrated that digital media positively impacts mathematics learning outcomes, and Zhang and Ma (2023) confirmed the effectiveness of PjBL on academic achievement, there is a distinct lack of structured, development-based research that encapsulates direct proportion concepts within a Scratch-based e-module using the Plomp development model. Most existing studies either focus solely on the computational thinking aspects of Scratch or utilize digital modules without integrating visual programming projects as the core mechanism for conceptualizing proportional reasoning. Therefore, this research aims to fill this critical gap by developing a Scratch-based e-module on direct proportion that meets the criteria of validity, practicality, and effectiveness, ultimately providing a novel, innovative, and meaningful digital learning resource to enhance the mathematical conceptual understanding of eighth-grade junior high school students..

METHOD

This study employed a development research approach based on the Plomp model to systematically design, evaluate, and refine the Scratch-based e-module on direct proportion. The Plomp model comprises three iterative phases: preliminary research, prototyping phase, and assessment phase. This systematic approach allows for formative evaluation and continuous revision to ensure the final product meets the required educational standards. The research was conducted at SMP Tunas Harapan Jaya during the even semester of the 2025/2026 academic year. Participants were selected using purposive sampling techniques, tailored to the specific requirements of each developmental stage. In the preliminary research and initial trial phases, 10 eighth-grade students from class VIII-B were involved to

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evaluate the readability and initial usability of the prototype. Subsequently, the limited trial engaged 27 different students from the same class to gather comprehensive data on the e-module's practicality. Finally, the assessment phase involved the full implementation of the product with 38 eighth-grade students from class VIII-A, who had not participated in the prior trials, to objectively measure the e-module's effectiveness in enhancing their mathematical conceptual understanding.

Data collection instruments were specifically designed to align with the objectives of each developmental phase, focusing on three core quality criteria: validity, practicality, and effectiveness. To measure validity, structured validation sheets were administered to three experts—comprising a material expert, a media expert, and an instrument expert—who evaluated the e-module's content, eXeLearning-based design, and Scratch integration using a four-point Likert scale. Practicality was assessed through student response questionnaires distributed during the limited trial to gauge the e-module's usability, interactivity, and overall appeal from the learners' perspectives. To determine effectiveness, a mathematical conceptual understanding test consisting of essay questions was administered as both a pre-test and a post-test during the assessment phase. These tests were designed to measure students' abilities to restate concepts, classify objects, provide examples, and apply direct proportion algorithms to contextual problems before and after the intervention, reflecting the core indicators of mathematical conceptual understanding.

The data analysis techniques were divided into qualitative and quantitative approaches depending on the research phase. Qualitative analysis was utilized during the preliminary research to process interview and documentation data, identifying the foundational needs for the e-module's design. In the prototyping phase, quantitative descriptive analysis was applied to calculate the average scores from the expert validation sheets and student response questionnaires, which were then categorized to determine the validity and practicality levels. For the assessment phase, quantitative inferential statistics were employed to analyze the pre-test and post-test scores. Prior to hypothesis testing, the Shapiro-Wilk test was conducted to confirm the normal distribution of the data. Subsequently, a Paired Samples t-Test was executed at a 0.05 significance level to determine the statistical significance of the improvement in students' conceptual understanding. Furthermore, Cohen’s d was calculated to measure the effect size, providing empirical evidence of the magnitude of the e-module's impact on students' cognitive development in mathematics.

RESULTS AND DISCUSSION

RESULTS

This study employed the Plomp development model, which consists of three main phases: *preliminary research*, *prototyping phase*, and *assessment phase*. The results of the development process are systematically presented based on the evaluation of the e-module's validity, practicality, and effectiveness.

Preliminary Research and Product Design

The preliminary research phase focused on analyzing the curriculum, learning materials, and student characteristics at SMP Tunas Harapan Jaya. The initial findings revealed that mathematics learning, particularly on the topic of direct proportion, was predominantly teacher-centered and lacked interactive digital media. Students struggled to visualize abstract proportional relationships and relied heavily on rote memorization of procedural formulas. To address these issues, a *Scratch*-based e-module integrating *Project-Based Learning* (PjBL) was designed. The final product, designated as Prototype IV, incorporates interactive materials, visual simulations, and two main constructionist projects (*Smart Fishing Net* and *Energy-Efficient Navigation*) that require students to apply direct proportion concepts using *Scratch* visual programming.

Validity and Practicality of the E-Module

The quality of the developed e-module was evaluated iteratively during the *prototyping phase* through expert validation and student trials.

Validity The e-module was validated by three experts: a material expert, a media expert, and an instrument expert. The initial prototype underwent several revisions based on expert feedback regarding interactivity, immediate feedback mechanisms, and digital layout optimization. After the final evaluation of the revised prototype, the e-module achieved an average validity score of 3.43 out of 4.00. Based on the evaluation criteria, this score falls into the "very

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valid" category, indicating that the e-module is highly appropriate for use in terms of content, language, presentation, and interactivity.

Practicality Practicality was assessed through student response questionnaires during the limited trial involving 27 eighth-grade students. The evaluation covered aspects of display, ease of use, interactivity, and learning benefits. The e-module achieved an average practicality score of 3.83, which is categorized as "very practical." This high score demonstrates that the *Scratch*-based e-module is user-friendly, visually engaging, and effectively supports students' independent learning processes without causing cognitive overload.

Effectiveness in Improving Mathematical Conceptual Understanding

The assessment phase was conducted to measure the effectiveness of the e-module in improving students' mathematical conceptual understanding. This phase involved 38 eighth-grade students (Class VIII-A) who used the e-module over four meetings. The effectiveness was determined by comparing the students' pre-test and post-test scores.

Descriptive Statistics The descriptive analysis of the pre-test and post-test scores is presented in Table 1.

Table 1. Descriptive Statistics of Pre-test and Post-test Scores

Statistical Measure	Pre-test	Post-test
Number of Students (N)	38	38
Mean Score	42.50	81.32
Standard Deviation	11.24	9.87
Minimum Score	20.00	60.00
Maximum Score	65.00	98.00

Table 1 shows a substantial increase in the mean score from 42.50 on the pre-test to 81.32 on the post-test. Furthermore, the standard deviation decreased from 11.24 to 9.87, indicating that the students' conceptual understanding became more uniform and consistently high after the intervention.

Normality Test Prior to hypothesis testing, a normality test was conducted using the Shapiro-Wilk test due to the sample size ($N < 50$). The results showed that the significance value for the pre-test was 0.214 and for the post-test was 0.341. Since both values are greater than the significance level of 0.05, it can be concluded that the data from both tests are normally distributed, fulfilling the assumption for parametric testing.

Hypothesis Testing To determine the significance of the improvement, a Paired Samples t-test was performed. The results of the hypothesis test are summarized in Table 2.

Table 2. Results of the Paired Samples t-Test

Variable	Mean Pre-test	Mean Post-test	Mean Difference	t-value	df	Sig. (1-tailed)	Decision
Conceptual Understanding	42.50	81.32	38.82	21.456	37	0.000	H_0 Rejected

As shown in Table 2, the Paired Samples t-test yielded a significance value of 0.000 ($p < 0.05$). Therefore, the null hypothesis (H_0) is rejected, and the alternative hypothesis (H_1) is accepted. This confirms that there is a statistically significant difference between students' conceptual understanding before and after using the *Scratch*-based e-module.

4. Effect Size Analysis To measure the magnitude of the e-module's impact, an effect size analysis was calculated using Cohen's d. The calculation utilized the mean difference and the pre-test standard deviation. The analysis yielded a Cohen's d value of 3.45. According to Cohen's criteria, a value of $d \geq 0.80$ is categorized as a "large" effect. The exceptionally high effect size of 3.45 indicates that the integration of *Scratch* programming and PjBL within the e-module has a very large and practically significant impact on enhancing students' mathematical conceptual understanding in direct proportion material.

DISCUSSION

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The results of this study demonstrate that the developed Scratch-based e-module achieved a "very valid" category, indicating that the integration of multimedia elements significantly enhances the quality of learning materials. According to Daryanto (2013), the use of appropriate and engaging learning media can significantly improve students' conceptual understanding because good media is capable of presenting abstract concepts in a more concrete format. This is further supported by Arsyad (2014), who argues that technology-based learning media offers the distinct advantage of presenting material visually and interactively, allowing students to learn at their own pace. Furthermore, the systematic design of the e-module aligns with the principles of instructional design, where incorporating verbal information, intellectual skills, and cognitive strategies ensures that the content is easily comprehended by learners (Fadli, 2020).

The high validity score also reflects the successful integration of interactive features that transform the e-module from a static digital text into a dynamic learning environment. Sukiman (2012) emphasizes that an effective instructional module must be self-instructional and self-contained, providing learners with structured experiences, examples, and interactive exercises to measure their own comprehension. The addition of immediate feedback mechanisms and Scratch simulations directly addresses this requirement, as interactive digital modules have been proven to significantly increase student activity and learning autonomy compared to conventional methods (Tarigan et al., 2021). Moreover, the development of interactive digital e-modules confirms that digital interactivity positively impacts critical thinking and conceptual mastery by allowing students to manipulate variables in real-time (Cynthia et al., 2023).

In terms of practicality, the e-module received a "very practical" rating from students, highlighting its user-friendly interface and high level of engagement. The utilization of technology in mathematics learning not only increases accessibility but also positively impacts students' learning interest, creating a more inclusive and innovative environment (Sulistyowati & Setyoningsih, 2023). This aligns with the findings that digital interventions significantly enhance students' problem-solving abilities and overall academic engagement when the technology is seamlessly integrated into the curriculum (Denpasar & Indah, 2023). Additionally, the practicality of the e-module is reinforced by its ability to foster digital literacy, as students are not merely consuming digital content but are actively navigating and utilizing digital tools to construct their knowledge (Nurfahrani et al., 2023).

The high practicality score also reflects the e-module's relevance to the demands of the digital era, where students are expected to possess both technological fluency and academic competence. The integration of digital educational games and design tools in STEM learning has been shown to be highly effective in maintaining student motivation and reducing cognitive load during complex problem-solving tasks (Gui et al., 2023). Furthermore, the concurrent journey of sustainable development goals and the fourth industrial revolution requires educational materials that are adaptive, user-friendly, and capable of bridging the gap between traditional learning and modern technological applications (Islam et al., 2022). Consequently, the e-module's practicality is not just about ease of use, but also about its capacity to prepare students for a digitally driven society by making learning mathematics a relevant and enjoyable experience (Kosasih, 2021).

The assessment phase revealed a highly significant improvement in students' mathematical conceptual understanding, with the mean score increasing from 42.50 to 81.32 and a large effect size (Cohen’s d = 3.45). This substantial improvement addresses the persistent difficulties students face in proportional reasoning, which Lamon (2012) identifies as one of the highest levels of mathematical reasoning required in junior high school. A deep understanding of proportionality cannot be achieved merely through the rote memorization of formulas; rather, it requires relational understanding that connects abstract concepts to real-world situations (Van de Walle et al., 2013). By contextualizing direct proportion within familiar scenarios, the e-module helps students overcome the common pitfalls of misidentifying proportional relationships, a struggle frequently observed in conventional learning settings (Hobri et al., 2018).

The effectiveness of the e-module is deeply rooted in the theory of constructionism, which posits that learning is most effective when students are actively involved in constructing meaningful, shareable artifacts. Papert and Harel (1991) define this paradigm as "learning-by-making," asserting that knowledge is most effectively built when students are directly involved in creating something that can be seen, tested, and shared with others. This philosophy is

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actualized in the e-module through projects like Smart Fishing Net and Energy-Efficient Navigation, providing an optimal learning environment that features activities directed toward meaningful learning and presents real challenges (Edith et al., 2009). Unlike traditional constructivism, constructionism adds the crucial dimension that learning becomes profoundly meaningful when participants engage in creating a useful product that solves specific problems based on the instructional material (Rob, 2018).

The integration of Scratch as a visual programming platform serves as the primary catalyst for transforming abstract mathematical concepts into concrete, manipulable objects. Resnick et al. (2009) identify the core principles of Scratch as being more tinkerable, more meaningful, and more social, allowing students to freely experiment and visually represent abstract mathematical relationships without being hindered by complex syntax. When students create animations and simulations that directly reflect the mathematical concepts they are learning, they build a much deeper conceptual understanding compared to passive learning methods (Kafai & Burke, 2013). This is corroborated by longitudinal studies showing that integrating visual programming languages across the curriculum significantly enhances students' computational thinking, creativity, and ability to grasp complex academic concepts (Sáez-López et al., 2019).

Furthermore, the implementation of Project-Based Learning (PjBL) within the e-module provides a robust framework for fostering active engagement and contextual understanding. Kazu et al. (2022) demonstrated through meta-analytical research that students in classes implementing PjBL and hybrid learning models achieved significantly higher conceptual understanding scores and exhibited greater active engagement. This approach is deeply rooted in authentic learning theories, as PjBL provides opportunities for students to explore and develop their multiple intelligences by engaging in carefully designed projects that reflect real-world challenges (Darmawati & Mustadi, 2023). The impact of PjBL on student learning effects is consistently positive, as it shifts the focus from procedural memorization to the active application of knowledge in solving contextual problems (Zhang & Ma, 2023).

The significant gain in conceptual understanding also serves as a direct remedy to the limitations of conventional mathematics instruction previously identified in the literature. Suryanto (2019) highlights that one of the primary reasons students struggle with proportion-related problems is their fundamental lack of conceptual understanding, which prevents them from distinguishing between direct and inverse proportions in varied contexts. This difficulty is often exacerbated by word problems, where a majority of students experience severe difficulties because they have a weak conceptual grasp and struggle to connect abstract concepts with contextual narratives (Rahmawati, 2020). By providing interactive simulations and step-by-step contextual scaffolding, the e-module directly addresses the minimal variation in teaching methods that traditionally hinders students from building accurate mathematical concepts (Rizky & Surya, 2017).

Finally, beyond conceptual understanding, the use of the Scratch-based e-module inadvertently fostered students' logical thinking and computational skills. Analyzing computational thinking studies reveals that Scratch programming significantly improves students' ability to structure algorithms, debug errors, and think logically when faced with complex tasks (Stewart & Baek, 2023). The process of designing Scratch projects requires students to apply computational thinking skills, which directly correlates with improved mathematical achievement and logical reasoning (Jiang & Li, 2021). Consequently, the systematic problem-solving approach required in Scratch programming naturally enhances students' logical thinking capabilities in mathematics, as they learn to break down complex proportional problems into manageable, sequential code blocks (Brennan & Resnick, 2012).

CONCLUSION

This study successfully developed a Scratch-based e-module on direct proportion for eighth-grade students using the Plomp development model. The comprehensive evaluation results demonstrated that the e-module strictly meets the required criteria of validity, practicality, and effectiveness. In terms of validity, expert evaluations yielded an average score of 3.43, categorizing it as very valid. Regarding practicality, student response questionnaires during the limited trial produced an average score of 3.83, indicating a very practical level of usability and engagement. Furthermore, the assessment phase confirmed the e-module's high effectiveness in significantly enhancing students' mathematical conceptual understanding. The average score increased remarkably from 42.50 on the pre-test to 81.32

on the post-test. Statistical analysis using the Paired Samples t-test revealed a highly significant improvement, while the effect size analysis yielded a Cohen's d value of 3.45, indicating a remarkably large educational impact. In conclusion, the integration of Scratch visual programming and Project-Based Learning within this interactive e-module provides a highly effective, valid, and practical digital learning solution. It is strongly recommended for mathematics educators as an innovative instructional resource to foster deep conceptual mastery of direct proportion in junior high school classrooms.

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