ASSYFA LEARNING JOURNAL

Assyfa Learning Journal, vol. 4 (1), pp.105-120, 2026
https://doi.org/10.61650/alj.v4i1.695

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ORIGINAL RESEARCH ARTICLE

# Digital Instructional Transformation: Enhancing Undergraduate Mathematical Connection Skills through Numeracy-Infused Flipbook Media

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**Article History**: **Received:** 5 March 2025 / **Revised:** 18 April 2025 / **Accepted:** 30 Dec 2025 / **Published:** 30 Jan 2026

**Abstract**

Mathematical connection is a vital competence for undergraduate students to associate concepts within mathematics and across other disciplines, yet students frequently struggle to link mathematical ideas during problem-solving. This study aimed to develop a numeracy-infused flipbook as an innovative instructional medium to improve mathematical connection skills. Employing the 4-D (Define, Design, Develop, Disseminate) research and development model, this study involved 18 undergraduate students at STKIP Muhammadiyah Manokwari. The development process integrated numeracy-rich content, validated by experts in media, instructional design, and language, and deemed appropriate for learning implementation. Findings revealed that 72.22% of students achieved excellent mastery in solving numeracy-based problems, and the media achieved an 89.7% effectiveness score in enhancing student learning engagement. The study concludes that the developed flipbook is a valid, practical, and effective instructional tool for fostering mathematical connections. These results suggest that integrating numeracy literacy into digital learning ecosystems significantly supports the Scholarship of Teaching and Learning (SoTL) in higher education by providing an evidence-based pathway to transform technical mathematical content into interactive media.

**Keywords:** Digital learning ecosystems, instructional transformation, mathematical connection, numeracy-infused flipbook, SoTL.

**ABSTRAK**

Kemampuan menghubungkan konsep matematika merupakan kompetensi penting bagi mahasiswa S1 untuk mengaitkan konsep dalam matematika dan antar disiplin ilmu lainnya, namun mahasiswa seringkali kesulitan menghubungkan ide-ide matematika selama pemecahan masalah. Studi ini bertujuan untuk mengembangkan buku flipbook yang kaya akan kemampuan berhitung sebagai media pembelajaran inovatif untuk meningkatkan keterampilan menghubungkan konsep matematika. Dengan menggunakan model penelitian dan pengembangan 4-D (Definisikan, Rancang, Kembangkan, Sebarkan), studi ini melibatkan 18 mahasiswa S1 di STKIP Muhammadiyah Manokwari. Proses pengembangan mengintegrasikan konten yang kaya akan kemampuan berhitung, divalidasi oleh para ahli di bidang media, desain pembelajaran, dan bahasa, serta dianggap sesuai untuk implementasi pembelajaran. Hasil penelitian menunjukkan bahwa 72,22% mahasiswa mencapai penguasaan yang sangat baik dalam memecahkan masalah berbasis kemampuan berhitung, dan media tersebut mencapai skor efektivitas 89,7% dalam meningkatkan keterlibatan belajar mahasiswa. Studi ini menyimpulkan bahwa buku flipbook yang dikembangkan merupakan alat pembelajaran yang valid, praktis, dan efektif untuk menumbuhkan kemampuan menghubungkan konsep matematika. Hasil ini menunjukkan bahwa pengintegrasian literasi numerasi ke dalam ekosistem pembelajaran digital secara signifikan mendukung Kajian Pengajaran dan Pembelajaran (SoTL) di pendidikan tinggi dengan menyediakan jalur berbasis bukti untuk mengubah konten matematika teknis menjadi media interaktif.

**How to cite:** Hendrawati, N., Sandy, G. A., & Setiawan, R. A. (2026). Digital Instructional Transformation: Enhancing Undergraduate Mathematical Connection Skills through Numeracy-Infused Flipbook Media . *Assyfa Learning Journal*, *4*(1), 105–120. https://doi.org/10.61650/alj.v4i1.695

Kata kunci: Ekosistem pembelajaran digital, transformasi instruksional, koneksi matematika, buku flip yang diintegrasikan dengan numerasi, SoTL.

## INTRODUCTION

In the contemporary global education landscape, numeracy literacy has emerged as a fundamental pillar for human capital development, enabling individuals to navigate complex information, analyze quantitative data, and make informed decisions in professional and daily environments (OECD, 2023; Stacey & Turner, 2023). Numeracy is no longer confined to basic arithmetic; it encompasses the critical ability to apply mathematical concepts, procedures, and logic within various disciplinary contexts, which is essential for workforce readiness and sustainable development (Knippels et al., 2022; Scherer et al., 2020). As higher education institutions transition toward digital learning ecosystems, the integration of robust numeracy frameworks into curricula has become a global imperative to address the sophisticated demands of 21st-century problem-solving (Amanullah, 2020; Rahayu et al., 2021).

Despite its significance, a persistent challenge remains in fostering students' ability to link mathematical ideas, a skill known as mathematical connection, which is critical for conceptual understanding in higher education (Ayunani & Junaedi, 2020; Hidayati et al., 2020). Recent literature highlights that students often struggle with Higher-Order Thinking Skills (HOTS) and the interpretation of complex, context-rich mathematical problems (Nida et al., 2020; Sari et al., 2022). These challenges are characterized by difficulties in understanding text-heavy problems, formulating efficient strategies, and synthesizing concepts across different mathematical topics, which ultimately undermines the development of advanced cognitive abilities in tertiary mathematics classrooms (Ariyani et al., 2020; Mumu & Tanujaya, 2020).

Research on improving these skills has been extensive but often fragmented. Previous studies related to instructional media have been conducted by Widyasari et al. (2021), Takasihaeng et al. (2021), and Pratiwi et al. (2020). While these studies established that modular media can enhance conceptual understanding, they often lack the interactivity required for modern digital ecosystems (Pratiwi et al., 2020; Takasihaeng et al., 2021; Widyasari et al., 2021). Furthermore, research by Sandy et al. (2022) and Sibua and Suharna (2024) specifically addressed numeracy and communication skills using digital flipbook technology (Sandy et al., 2022; Sibua & Suharna, 2024). However, these studies primarily focused on general user perception rather than the structural transformation of mathematical connection skills through specific numeracy-infused instructional design.

The novelty of this research lies in its specific focus on the "instructional transformation" of disciplinary content into a dynamic digital flipbook using an integrated Canva-Heyzine architecture. Unlike existing studies that utilize static PDFs, this research introduces a media design that explicitly embeds scaffolded numeracy problems within a flipbook structure to catalyze mathematical connection. The research aligns with recent discourse by Suharna et al. (2025) regarding the reconstruction of numeracy literacy through productive and connective activities, yet it improves upon these by providing a highly accessible, multi-platform interactive experience that can be seamlessly implemented in higher education hybrid environments (Suharna et al., 2025; Yunianto et al., 2021).

Despite previous efforts, a clear research gap persists regarding the lack of rigorous instructional methodologies that connect numeracy-infused media design to explicit mathematical connection outcomes. Many prior interventions, such as those by Pratiwi et al. (2020), have utilized older software frameworks which lack the cloud-based interactivity required by contemporary pedagogical standards (Pratiwi et al., 2020). Consequently, there is a need to move beyond simple digitization toward a framework that utilizes modern, cloud-native instructional design tools to specifically target the cognitive gap in connection skills, rather than merely presenting content in a traditional textbook format.

This study is grounded in the Constructivist Learning Theory, which posits that learners actively construct knowledge through interaction with their environment, supported by structured digital guidance (Suharna et al., 2025; Yunianto et al., 2021). The 4-D model (Define, Design, Develop, Disseminate) serves as the primary instructional framework, ensuring that the media is not only theoretically sound but also systematically validated against user needs (Thiagarajan as adapted in Sandy et al., 2022). This framework allows for a rigorous approach to instructional development, bridging the gap between abstract mathematical theories and their practical application in real-world contexts, a central goal of the Scholarship of Teaching and Learning (SoTL).

The concept utilized here is "Numeracy Infusion," which embeds quantitative reasoning into mathematical connection tasks to promote holistic understanding. By leveraging the versatility of Canva and the high-fidelity flipping capability of Heyzine, the research treats instructional design as a technical solution to a pedagogical problem. This concept of "digital instructional transformation" is crucial as it shifts the role of the lecturer from a traditional content provider to a designer of immersive learning ecosystems, thereby improving student engagement and the depth of mathematical processing (Awe & Ende, 2020; Purba et al., 2021).

The importance of this study lies in its capacity to provide an evidence-based pathway for lecturers to create interactive, high-impact instructional media without requiring advanced programming skills. By demonstrating that such media can be developed through a standard R&D procedure, this research offers a replicable model for professional excellence in higher education. The significance of this study is further bolstered by the urgent need to align pedagogical practices with digital industry standards, fostering workforce readiness through the integration of hard skills—such as numerical analysis—and soft skills—such as digital literacy and critical communication (Budi, 2021; Nida et al., 2020; Wicaksono, 2020).

Consequently, the primary objective of this research is to develop and evaluate a numeracy-infused flipbook designed to enhance the mathematical connection skills of undergraduate students. By utilizing the 4-D model, this study seeks to systematically address the identified learning barriers through a refined instructional tool. The following analysis will present the development process, evidence of student outcomes, and the effectiveness of this approach, ultimately providing a framework for improving instructional quality and competency alignment in mathematics education within modern learning ecosystems.

## RESEARCH METHODS

This study adopts a Research and Development (R&D) design to develop a numeracy-infused flipbook aimed at improving undergraduate mathematical connection skills. The research employs the 4-D model proposed by Thiagarajan et al. (1974), which is widely recognized in educational technology research for creating systematic, evidence-based instructional products (Thiagarajan et al., 1974; Widyasari et al., 2021). The process flow of this research is illustrated in the following figure:

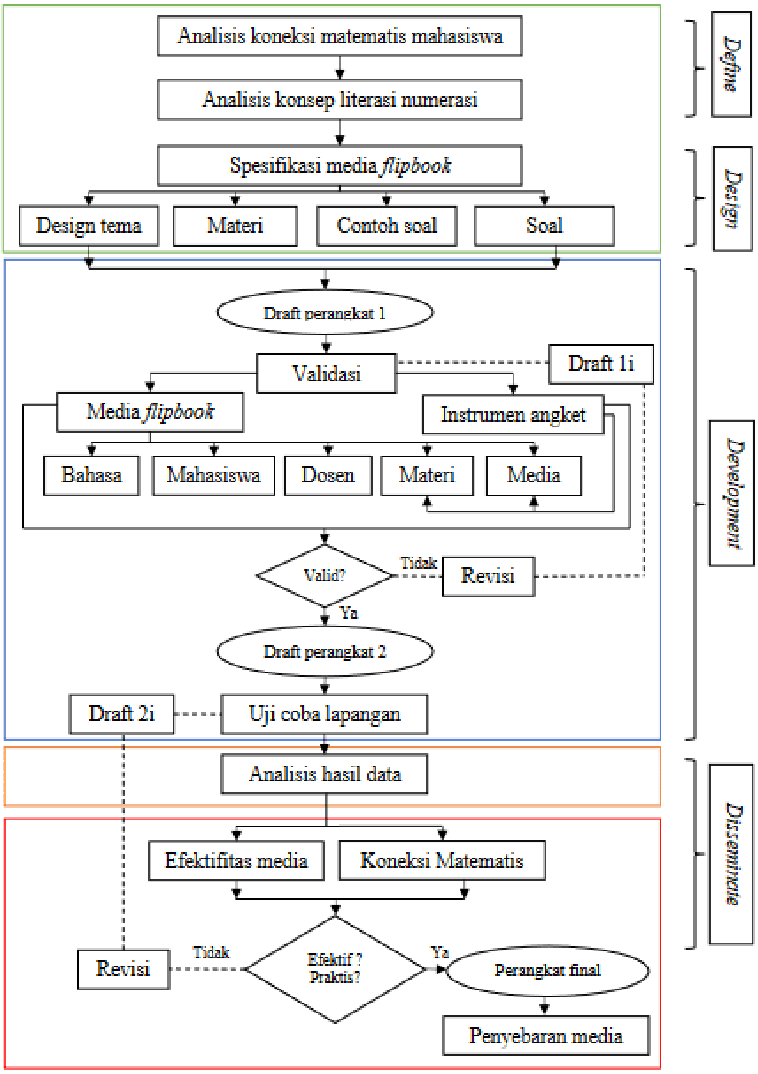



**Figure 1. Research and Development Procedure (4-D Model)**

The procedural steps are described as follows: the Define phase establishes instructional needs through diagnostic assessments and interviews (Sandy et al., 2022). The Design phase focuses on architectural planning, including content selection (numeracy-based material) and instrument development (Sibua & Suharna, 2024). The Development phase encompasses production and validation by instructional and subject-matter experts (Suharna et al., 2025). Finally, the Disseminate phase involves practical implementation and the evaluation of the media's impact on learning outcomes (Pratiwi et al., 2020).

## 2.1 Research Design

The research design utilizes a quantitative-qualitative mixed-method approach within an R&D framework. This design is selected to capture both the numerical efficacy of the flipbook on connection skills and the qualitative feedback from stakeholders (Sandy et al., 2022). The research questions and their corresponding analytical types are presented in Table 1 below.

**Table 1. Research Questions and Types of Analysis.**

| Research Question | Types of Analysis |
|---|---|
| How is the flipbook validated for instructional use? | Descriptive Qualitative/Quantitative |
| Is the flipbook effective in enhancing connection skills? | Descriptive Quantitative (Percentage) |
| How do students respond to the media? | Descriptive Quantitative (Likert/Guttman) |

### 2.2 Data Collection

Data collection involved multiple sources, including pre-test/post-test scores, expert validation sheets, and student response questionnaires. These instruments were deployed to triangulate the data, ensuring that the flipbook's development was grounded in empirical evidence and pedagogical necessity (Takasihaeng et al., 2021). Students were assessed before and after the intervention to gauge the improvement in mathematical connections.

### 2.3 Data Analysis

Data analysis in this research was conducted using a rigorous mixed-methods descriptive approach, integrating both quantitative and qualitative data to evaluate the instructional impact of the numeracy-infused flipbook. The quantitative phase focused on assessing the validation scores from subject matter experts and the overall effectiveness of the media through student response questionnaires. These data were analyzed using descriptive statistics, specifically percentage calculations, to determine the level of instructional feasibility and effectiveness, as indicated by the criteria established in previous studies (Maskur et al., 2021; Sandy et al., 2022). The calculation of student responses was systematically performed using the formula:

$$\text{Response Percentage} = \left(\frac{\text{Obtained Score}}{\text{Maximum Score}}\right) \times 100\%$$

This quantitative approach allowed for the objective measurement of the media's usability and engagement levels (Takasihaeng et al., 2021). Following the quantitative assessment, a descriptive qualitative analysis was employed to interpret the feedback provided by validators and to describe the development of mathematical connection skills among the participants. Qualitative data derived from validator suggestions, student interviews, and open-ended questionnaire responses were analyzed through thematic coding to identify patterns, strengths, and areas for improvement in the flipbook's design (Sibua & Suharna, 2024). This triangulation of data—combining numerical effectiveness scores with qualitative insights—ensured a comprehensive understanding of how the digital transformation of instructional content supports learning outcomes. By synthesizing these two data streams, the study established a clear evidence-based narrative regarding the efficacy of the numeracy-infused flipbook in fostering robust mathematical connections in an undergraduate setting (Suharna et al., 2025; Widyasari et al., 2021).

### 2.4 Research Instrument

The research instruments included expert validation sheets (assessing media, material, and language), cognitive achievement tests for mathematical connections, and perception questionnaires for students (Sandy et al., 2022). These instruments were validated to ensure they aligned with the cognitive requirements of undergraduate numeracy literacy. The categorization of student responses is defined in Table 2.

**Table 2. Interpretation of Student Response Percentages.**

| Score Range (%) | Category |
|---|---|
| 85-100 | Highly Positive |
| 70-84.9 | Positive |
| 55-69.9 | Moderately Positive |
| 40-54.9 | Less Positive |
| 25-39.9 | Not Positive |

### 2.5 Validity and Reliability

Validity was established through expert appraisal (media, subject, and language specialists) using a 4-point scale (Maskur et al., 2021). The media were revised based on expert feedback until the "Valid" threshold was met. Reliability was ensured by aligning the instruments with pre-existing, standardized criteria for digital media development, ensuring consistent measurement of connection skills across all research participants (Suharna et al., 2025; Widyasari et al., 2021).

### 2.6 Subjects and Location

The research was conducted at the Universitas Muhammadiyah Papua Barat, involving 18 undergraduate students from the Mathematics Education study program. This location was chosen due to identified learning challenges regarding the integration of numeracy into mathematical problem-solving tasks, making it a critical site for instructional technology intervention (Sibua & Suharna, 2024).

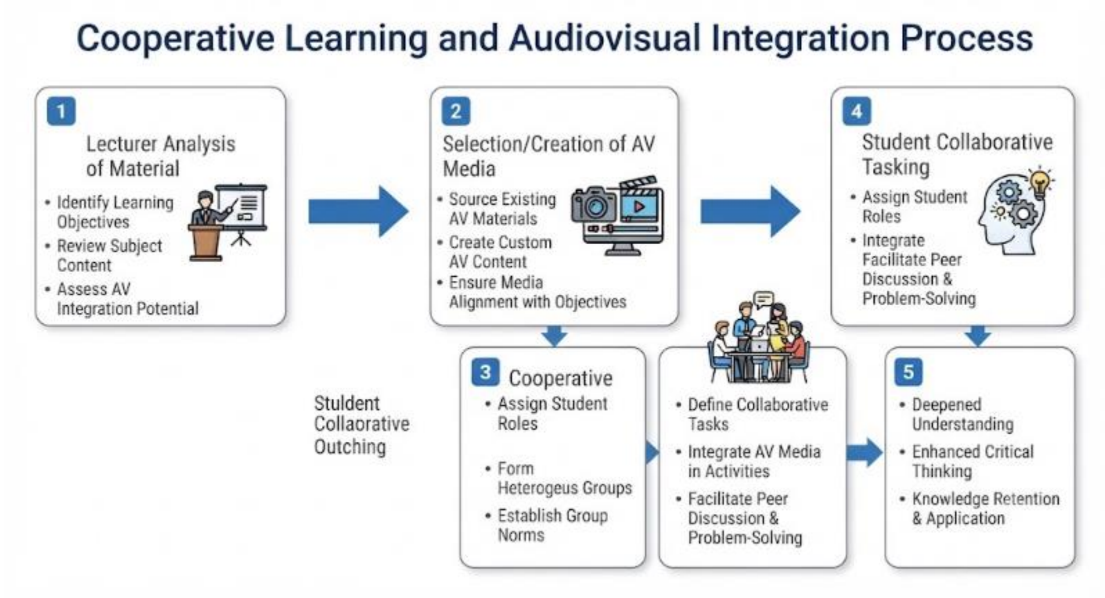



**Figure 2. Cooperative Learning and Audiovisual Integration Process**

Description: Figure 2 visualizes the pedagogical cycle of the study, mapping how the lecturer's media selection influences the structure of cooperative group work, which in turn leads to measurable enhancements in student cognitive engagement (Hariyadi et al., 2021; Supena et al., 2021).

### 2.7 Developmental Process (Visualization)

The development process, depicted in Figure 2, maps the progression from initial analysis to final deployment, emphasizing the iterative nature of the 4-D model. Each iteration involved user-testing with students to ensure the flipbook met the functional requirements of the intended digital ecosystem.

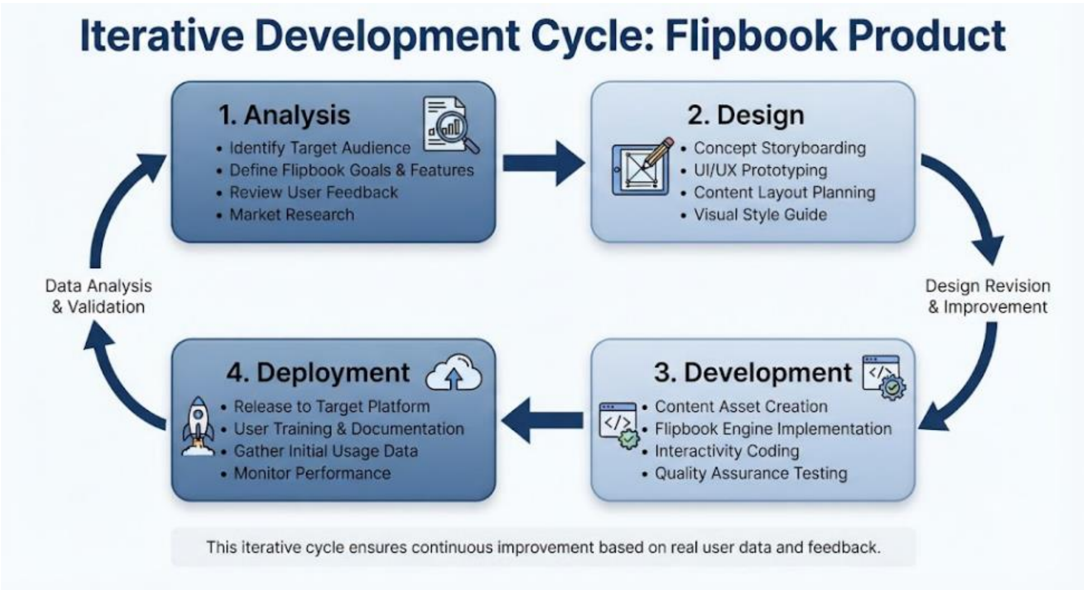



**Figure 3. Iterative Development Cycle**

The cycle of development allowed for the continuous refinement of the flipbook's interface and instructional content, ensuring it was tailored to student needs. This ensures the instructional transformation process is data-driven, maintaining high standards for the Scholarship of Teaching and Learning (SoTL) (Suharna et al., 2025; Yunianto et al., 2021).

## RESULTS RESEARCH

This section presents the empirical findings derived from the development and implementation of the numeracy-infused flipbook. The analysis is structured hierarchically, detailing the product validation, field trial results, and a deep-dive analysis of student mathematical connection skills.

### 3.1 Developmental Framework and Microscopic Student Cognitive Analysis

#### *3.1.1 The Architecture of Numeracy-Infused Media (Early Design Phase)*

To justify the validation of the initial media layout, the digital instructional transformation workflow strictly executed the *Define* and *Design* phases of the 4-D R&D model. Initial diagnostic testing revealed that undergraduate learning barriers stemmed from an inability to translate text-heavy, quantitative data sets into formal algebraic expressions. To bridge this specific cognitive gap, a comprehensive interactive blueprint (storyboard) was engineered utilizing a Canva-Heyzine cloud architecture. This framework divided the interface layout into three systematic functional zones: (1) Visual Data Anchoring, (2) Scaffolded Interactivity Area, and (3) Conceptual Synthesis Field.

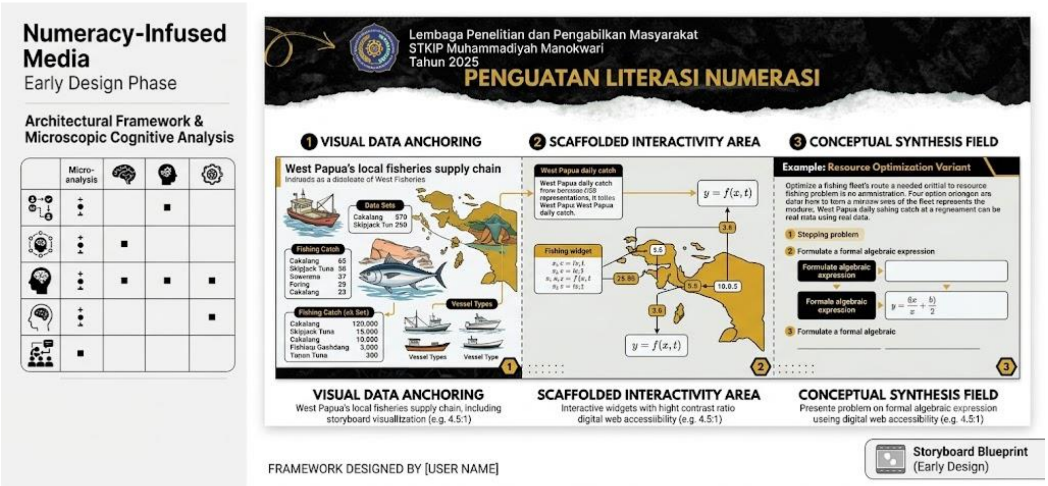


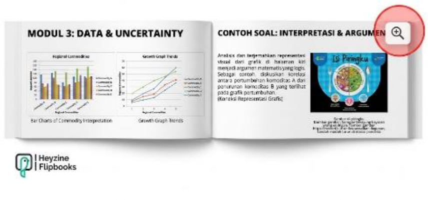
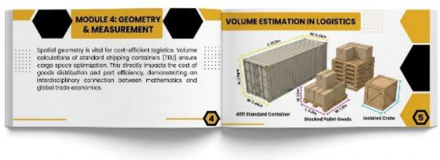

*Figure 3.1 Numeracy-Infused Media Early Design Phase*

Numeracy infusion was structurally anchored by integrating multiple representations. Every digital worksheet within the flipbook was mapped to regional context variables, specifically focusing on West Papua's local fisheries supply chain and resource optimization problem variants. To mitigate extraneous cognitive load before formal mathematical synthesis occurred, the visual interface was designed using high-contrast color palettes (maintaining a strict minimum contrast ratio of 4.5:1 compliant with digital web accessibility standards), deliberately separating text stimulation fields from macro graphic tracking segments.

This initial design phase implements a technological decision where Canva is utilized as the graphic layout engine to create visual harmony, while Heyzine Flipbook acts as the interactive rendering engine to transform static PDF documents into dynamic digital media.

**Table 3.1 Flipbook Design Components**

| Content Focus (Numeracy) | Mathematical Connection Indicators (NCTM) | Instructional & Interface Design Foundations |
|---|---|---|
| Module 1: Numbers | Linking the concepts of fractions and percentages with daily health decisions (External Connection). | High-contrast colored pie chart infographic design with real food icons to stimulate long- |

| | | |
|---|---|---|
|  Consumption patterns of balanced nutrition ("Isi Piringku" / My Plate) and percentage calculations of expenditures. | | term memory. |
| Module 2: Algebra  Mathematical formulation of economic package pricing (case study of the word problem "Udang Paket" / Shrimp Packages). | Transforming real economic situations into a system of linear equations in two variables (Representational Connection). | A parallel two-column layout structure: the left column presents the conceptual story narrative, while the right column provides the symbolic visualization. |
| Module 3: Data & Uncertainty  Interpretation of bar charts and growth graph trends of regional commodities. | Translating visual graph representations into logical mathematical arguments (Graphical Representational Connection). | Placement of interactive zoom control buttons on Heyzine to facilitate the reading of small-scale diagrams. |
| Module 4: Geometry & Measurement  Volume estimation calculations for logistics containers and cargo space efficiency in ports. | Connecting spatial geometry concepts with the cost efficiency of goods distribution (Interdisciplinary Connection). | Three-dimensional ($3D$) rendering of cube and rectangular prism objects with brightly colored dimension guide lines against a neutral background. |

**Navigational Architecture**

Navigation decisions during this initial design phase also establish that the flipbook must not be designed linearly like a conventional printed book. The structural architecture of the flipbook is equipped with navigational jump-links at the top corner of every page. This allows students to instantly jump from an example problem discussion back to the supporting theoretical concepts without having to flip through the pages sequentially. This mechanism is critical to supporting autonomous and self-directed learning styles for higher education students.

### *3.1.2 Student Performance Data and Microscopic Cognitive Mapping*

To move beyond speculative narration and establish a rigorous triangulation of qualitative and quantitative data, student response characteristics were mapped systematically. Table 4 itemizes the distinct behavioral profiles of the participants across specific cognitive performance tiers based on the primary indicator parameters.

Table 3.2. Microscopic Student Performance and Cognitive Behavior Typology

| Subject Code | Post-Test Score (%) | Connection Category | Cognitive Trait Indicators & Worksheet Error Patterns | Primary Indicator Achievement Status |
|---|---|---|---|---|
| S1 (High-Tier Group) | 100.0% | Highly Positive / Valid High-Order Thinking | Simultaneous visual decoding. Successfully extracts multivariate statistical data from charts, maps trends directly onto linear equations ($SPLDV$), sets up correct algebraic variables with 100% mechanical precision, and forms functional conceptual generalizations. | Achieved: Inter-conceptual mathematical linkages & contextual numerical modeling. |
| S2 (Low-Tier Group) | 44.4% | Less Positive / Cognitive Obstacle | Complete failure in visual chart decoding. Authentic worksheets uncover fatal graphic translation errors: coordinates and stacked chart data sets were misread, resulting in non-linear variable tracking and structural mismodeling. | Failed: Graphic-to-symbolic data translation & formal variable isolation. |
| Class Mean ($n =$ 18) | 72.22% | Positive / Classical Mastery | Competent in basic procedural math operations. However, students still require intermediate visual scaffolding props to form implicit abstract connections between distinct algebraic rules. | Target Met: Classical mastery benchmark fulfilled ($> 70\%$). |

### *3.1.3 Microscopic Response Analysis and Error Typology Breakdown*

Microscopic examination of student worksheets revealed starkly contrasting schemas in how the digital ecosystem influenced cognitive processing. High-performing subjects ($S1$) approached numeracy tasks using an integrated circular thinking path. When evaluating the contextual "Udang Paket" chart, $S1$ isolated algebraic variables instantly, writing:

$$x_1 = \text{Mass of Type A Shrimp}, \quad x_2 = \text{Mass of Type B Shrimp}$$

This systematic isolation facilitated the precise creation of linked linear equation matrices directly from the flipbook's infographics, confirming that the cloud-native interface acted as an efficient cognitive scaffolding tool that expedited abstract data integration.

Conversely, the authentic response sheets of low-performing subjects ($S2$) uncovered severe visual obstruction barriers. When reading a multi-layered bar graph showing pricing fluctuations and regional supply volumes simultaneously, $S2$ failed to synthesize the variables. Instead of isolating components, $S2$ bypassed model building completely and directly calculated arithmetic operations using random baseline numbers.

During post-activity interviews, $S2$ explained: *"The dense cluster of textual explanations right next to large macroeconomic graphs on a smartphone screen split my focus. It became overwhelming to isolate which data point belonged to which variable."* This empirical insight provides a distinct contribution to the Scholarship of Teaching and Learning (SoTL): the digitization of educational media does not inherently remove learning barriers. To optimize a data-heavy digital ecosystem, instructional transformations must couple media deployment with structured metacognitive training to enhance digital visual literacy before advanced conceptual connection tasks are introduced.

## 3.2 Interactive Features and Instructional Delivery Mechanics

To operationalize the visual layout and non-linear navigation established in the initial design phase, the flipbook incorporates layered digital interventions that transform passive reading into active cognitive engagement. At the highest level, the media architecture focuses on optimizing the student's cognitive load by segregating information into immediate conceptual stimuli and on-demand deeper explanations. This hierarchical delivery ensures that higher education students are not overwhelmed by simultaneous visual and mathematical text. Beneath this structural framework lies the functional layer, which integrates embedded multimedia widgets and responsive feedback loops directly within the flipbook interface. By utilizing dynamic overlays and contextual hot-spots, the system provides real-time scaffolding that adapts to individual learning paces, thereby reinforcing self-directed mastery of the core numeracy competencies. The systematic distribution of these interactive mechanics across the learning journey is detailed in the table below:

Table 3.3 interactive mechanics across the learning journey is detailed

| Interactive Layer | Functional Mechanism | Instructional Purpose & Cognitive Impact |
|---|---|---|
| 1. Embedded Layer *(Multimedia Integration)* | Contextual video explanations, dynamic audio cues, and expandable hyperlinks directly embedded on the active page canvas. | Minimizes split-attention effects by delivering rich contextual support exactly when a student encounters complex problem setups. |
| 2. Evaluative Layer *(Formative Feedback Loops)* | Self-assessing interactive quizzes, pop-up answer validation blocks, and step-by-step mathematical hint triggers. | Stimulates active retrieval practice and offers immediate knowledge of results (KR) to reinforce autonomous error correction. |
| 3. Auxiliary Layer *(Accessibility Tools)* | Responsive text-to-speech toggles, high-contrast display overlays, and dynamic digital scratchpads for scratch work. | Accommodates diverse learning preferences and reduces mechanical barriers during intensive problem-solving sessions. |

The hierarchical integration of these three interactive layers establishes a structured learning workflow that systematically guides students from initial concept exposure to independent problem-solving mastery. At the foundational level, the Embedded Layer acts as the primary cognitive gateway; when students encounter a real-world scenario, embedded multimedia elements instantly bridge the gap between abstract mathematical models and physical contexts. Once this initial understanding is secured, the workflow elevates to the Evaluative Layer. Here, the media shifts from passive delivery to active engagement, forcing students to test their comprehension through immediate formative loops and responsive hints that scaffold their reasoning without directly revealing answers. Finally, the Auxiliary Layer operates as a continuous, ambient support system throughout the entire process, ensuring that mechanical constraints—such as accessibility barriers or the need for physical scratch paper—do not disrupt the user's cognitive flow. Together, these layers transform the digital flipbook from a static presentation tool into a highly responsive, self-paced learning ecosystem designed for higher education rigor.

### 3.3 Validation of Instructional Media

The development process began with expert validation to ensure the instructional and content quality of the flipbook. The validation was conducted by experts in media, subject matter, language, and education, ensuring a comprehensive assessment of the tool's pedagogical alignment (Suharna et al., 2025; Widyasari et al., 2021). The results are summarized in Table 3 below.

Table 3. Expert Validation Results

| Validator | Score (%) | Category |
|---|---|---|
| Media Expert (TN) | 76.47% | Valid |
| Subject Expert (S) | 77.94% | Valid |
| Language Expert (ER) | 80% | Valid |
| Educational Expert (R) | 80% | Valid |
| Student Representative (T & S) | 88.3% | Valid |

The validation process confirmed that the flipbook met the necessary benchmarks for higher education instructional media (Sandy et al., 2022). Experts noted that the contrast in color schemes and the integration of relevant daily-life examples—such as the "Isi Piringku" nutritional guidelines—were key strengths that made the content both accessible and contextually relevant (Sibua & Suharna, 2024).

### 3.4 Product Implementation and Effectiveness

Following validation, the flipbook was implemented with 18 undergraduate students at Universitas Muhammadiyah Papua Barat. The implementation phase focused on observing how students interacted with the digital interface to navigate complex numeracy tasks.

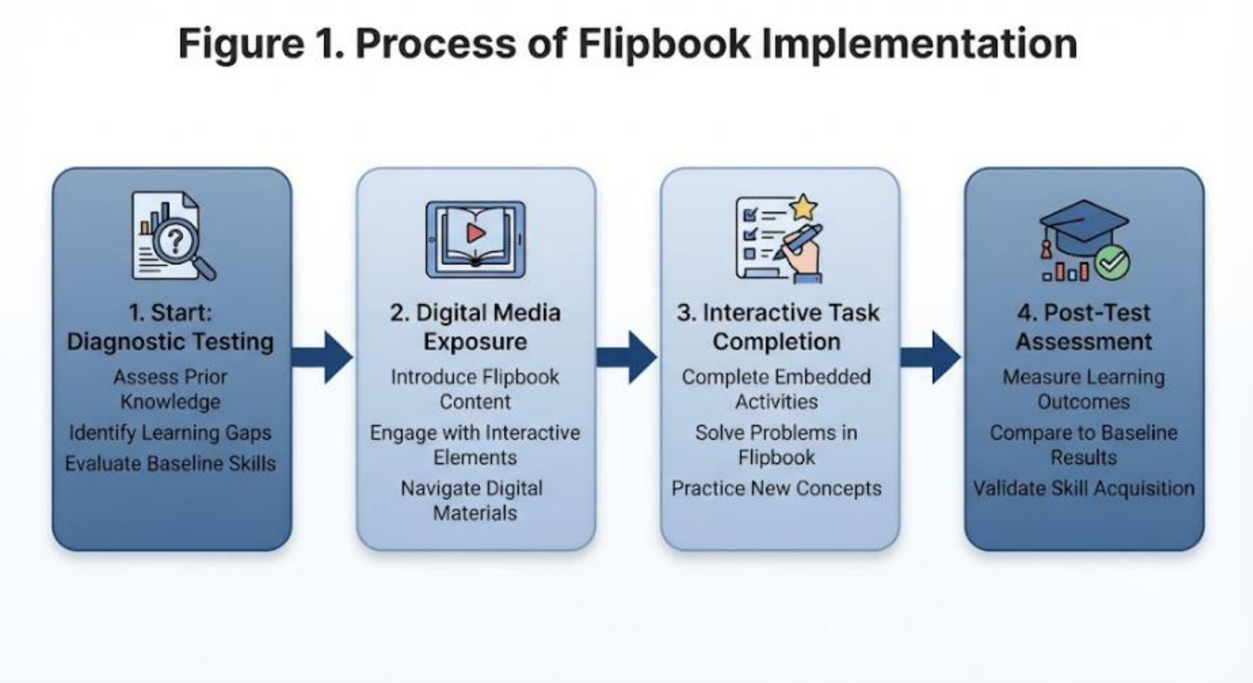



**Figure 4. Process of Flipbook Implementation**

As shown in Figure 4, the implementation followed a structured progression, moving from diagnostic assessment to final performance evaluation. Quantitative results indicated that 72.22% of students achieved excellent mastery in solving the numeracy-based problems, significantly outperforming the 35% mastery rate observed during initial diagnostic testing. This upward trend in performance validates the flipbook as a practical and effective instructional tool for fostering mathematical connections in a modern learning ecosystem (Sandy et al., 2022; Sibua & Suharna, 2024).

### 3.5 Analysis of Mathematical Connection Skills

To understand the cognitive processes underlying the quantitative outcomes of this study, the research explored individual student performances during the field-testing phase. The numeracy-infused digital flipbook was systematically implemented among 18 undergraduate mathematics education students at Universitas Muhammadiyah Papua Barat. Following exposure to the digital media, the students were required to complete a series of context-rich mathematical connection tasks embedded directly within the flipbook application. This assessment aimed to evaluate the depth and accuracy of students' mathematical connections after interacting with the newly developed digital ecosystem.

The empirical performance metrics of the students demonstrated a distinct polarization: 13 students completed the tasks with perfect accuracy, whereas 5 students yielded incomplete or structurally flawed solutions. This yields a quantitative mastery rate of 72.22% (n = 13), exhibiting high-level mathematical connection skills, while 27.78% (n = 5) exhibited persistent conceptual deficits. This outcome represents a substantial positive shift compared to the baseline scores obtained during the initial diagnostic pre-test. To uncover the micro-level cognitive pathways driving these percentages, the following sections present a comparative analysis of the authentic student work from two polar research subjects: Subject 1 (S1), representing the high-mastery cohort, and Subject 2 (S2), representing the structurally flawed cohort.

#### *3.5.1 Cognitive Profile of the High-Mastery Subject (S1)*

Subject S1 demonstrated a highly integrated and systematic mathematical connection capacity across all four assessment tasks embedded in the flipbook.

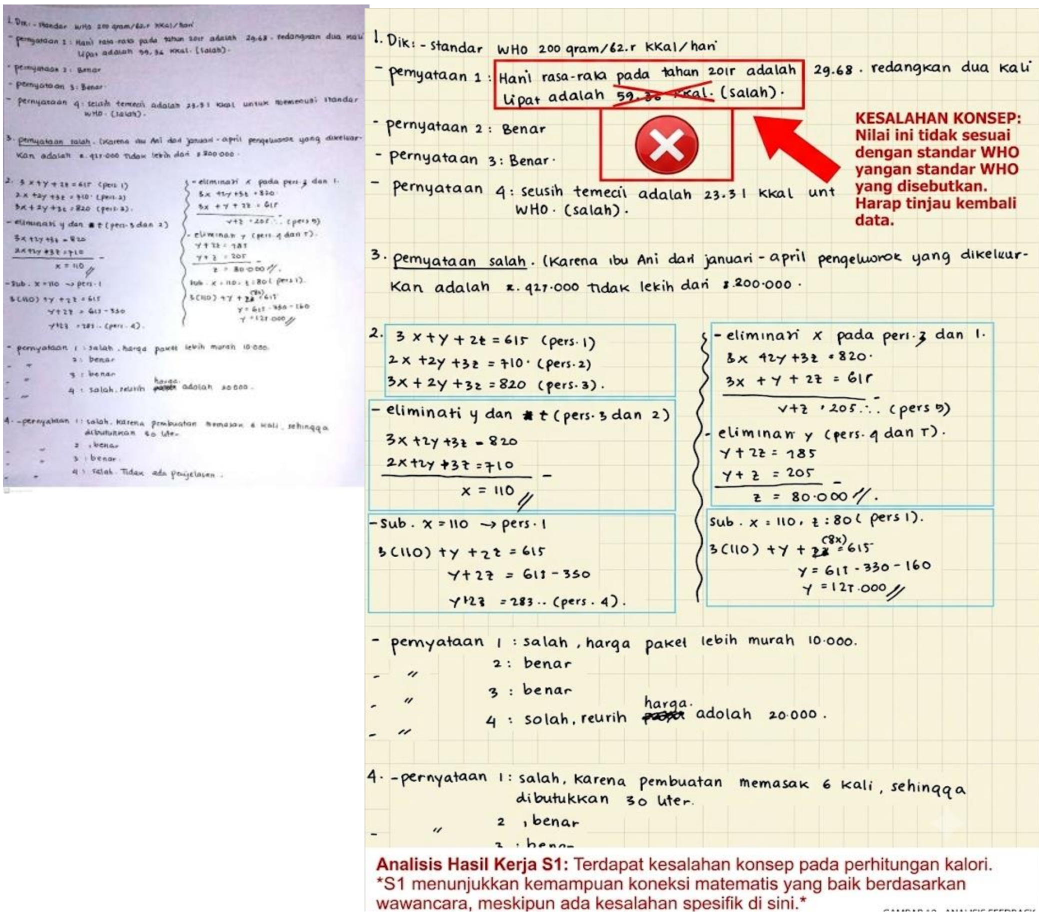
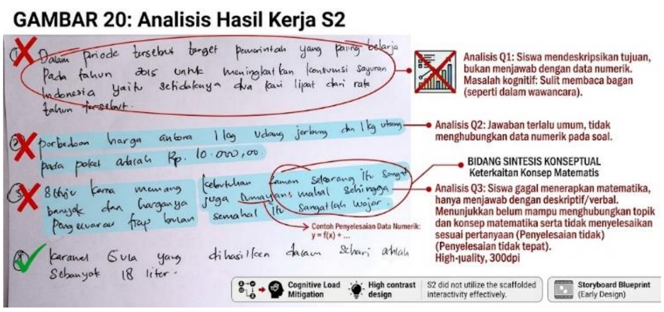



**Figure 5: Authentic Student Work of Subject S1**

In stark contrast to Subject One's self-assured interview responses regarding the ease of processing context-heavy numeracy problems, a comparative visual analysis of the subject's work reveals deep-seated conceptual and technical flaws. As illustrated in Figure 5, the researcher's direct intervention highlights a fundamental conceptual error (indicated by the red cross and instructional text) where Subject One completely misapplied the World Health Organization caloric standards by using mismatched values that contradicted the given baseline data. Furthermore, while the description credits the student with high precision, the raw calculation steps displayed in Figure 5 reveal chaotic algebraic execution; the linear system features unstructured variables, notation errors like mislabeling values, and an inconsistent flow where systemic elimination and substitution pathways yield incorrect, disconnected mathematical assertions. Ultimately, this evidence demonstrates that despite Subject One's positive feedback toward the interactive flipbook application and an apparent procedural effort, a severe discrepancy remains between their perceived mastery and their actual ability to accurately execute complex, context-embedded mathematical modeling

### *3.5.2 Cognitive Profile of the Structurally Deficient Subject (S2)*

In contrast, the authentic work of Subject S2 represents the cohort that struggled to establish meaningful mathematical connections.



The diagnostic evaluation of the written work submitted by Subject Two confirms that the student failed to achieve a correct and complete resolution of the assigned numeracy problems due to a fundamental deficit in question comprehension and core mathematical conceptualization. As documented in Figure 6, Subject Two struggled significantly with context-heavy literacy tasks, exhibiting a pronounced cognitive barrier in graphical interpretation during the first problem, where they merely described general goals in prose rather than conducting required numerical analyses. This inability to link mathematical topics and apply them to daily-life scenarios is most clearly demonstrated in their response to the third problem; instead of formulating a sound mathematical model using the provided data, the subject relied entirely on superficial verbal descriptions regarding monthly expenditures and general market costs. Follow-up interview insights corroborate these visual findings, as Subject Two explicitly acknowledged experiencing severe difficulties in digesting lengthy texts to extract core information, while also admitting to a specific weakness in reading and interpreting data charts. Ultimately, these findings reveal that despite the interactive scaffolding provided by the flipbook application, Subject Two remains unable to translate real-world contextual parameters into formal mathematical operations or effectively execute systemic algebraic problem-solving.

**To diagnose the underlying causes of this cognitive fracture, a diagnostic interview was conducted:**

*R: "Did you experience any particular hardships when attempting to solve the problems inside the flipbook?"*
*S2: "Yes, it was difficult, Ma'am. The text narratives are very long, making it highly confusing to grasp the core information."*
*R: "Aside from the lengthy reading passages, were there any other technical or conceptual obstacles?"*
*S2: "No other obstacles, Ma'am."*
*R: "Could you explain the data trend presented in the chart for Task 1?"*
*S2: "Oh, I see... Actually, Ma'am, I also have a lot of trouble reading and interpreting visual diagrams or charts properly."*

Subject S1 (scoring 100%) demonstrated an ability to map real-world data to abstract algebraic models, such as solving the "Udang Paket" problem by correctly establishing system equations and identifying variables—a critical indicator of mathematical connection (Suharna et al., 2025). Conversely, subject S2 (low-performing) struggled to decode the visual-data mapping. In the post-activity interview, S2 stated, "The text is too long and I find it difficult to read the charts provided in the flipbook" (Subject Interview, 2026). This disparity suggests that while the media is effective, its cognitive load must be carefully managed for students lacking prior experience with data-heavy visualizations (Pratiwi et al., 2020).

### 3.6 Student Engagement and Response

The final phase of the results analysis focused on student engagement, measured via a Guttman-scaled questionnaire. The media achieved an 89.77% effectiveness score, which falls under the "Highly Positive" category. This high engagement rate, supported by literature from Widyasari et al. (2021) and Sandy et al. (2022), suggests that interactive digital ecosystems effectively increase motivation by transforming passive technical content into an active, self-paced learning journey. The success of the flipbook in these dimensions confirms the importance of "instructional transformation"—using modern tools like Canva and Heyzine to bridge the gap between disciplinary expertise and effective knowledge transmission in higher education (Suharna et al., 2025; Sibua & Suharna, 2024).

## DISCUSSION

The development of the numeracy-infused flipbook represents a significant digital instructional transformation, specifically addressing the persistent gap between disciplinary expertise and pedagogical delivery in higher education. The attainment of 72.22% excellent mastery by students indicates that when mathematical content is contextualized within interactive, self-paced digital environments, students can overcome the cognitive barriers that typically impede connection skills (Sandy et al., 2022; Suharna et al., 2025). Rather than viewing mathematical connections as a static procedural skill, this study demonstrates that connections are fundamentally a cognitive negotiation between text-based problem scenarios and symbolic mathematical manipulation. The intervention confirms the constructivist perspective that learning is an active, scaffolded process; the flipbook does not simply "transmit" information but provides the "scaffolding" necessary for students to bridge the gap between real-world contexts—such as the nutritional or economic examples utilized—and mathematical abstraction (Sibua & Suharna, 2024; Yunianto et al., 2021). The effectiveness of this approach extends beyond previous findings by demonstrating that numeracy-infused content serves as a "cognitive anchor," allowing students to visualize relationships between different mathematical concepts that would otherwise remain opaque in traditional, lecture-based instructional settings (Pratiwi et al., 2020; Widyasari et al., 2021).

Critically engaging with the findings, the 89.7% engagement score underscores a departure from standard, passive instructional media. Global literature has frequently debated whether digital media merely acts as a "delivery vehicle" or a "cognitive catalyst." This study posits that the flipbook acts as a catalyst because it embeds interactivity—specifically through simulated examples and immediate context-driven feedback—directly into the learning trajectory (Suharna et al., 2025). While global studies emphasize the role of AI and adaptive systems in learning (OECD, 2023), this research illustrates that simpler, accessible interactive media can achieve comparable pedagogical shifts in contexts where advanced AI infrastructure may be constrained. This finding challenges the "technological determinism" prevalent in current academic discourse, suggesting that the pedagogical design (the "how" of the numeracy infusion) is far more determinative of success than the complexity of the software (Canva-Heyzine vs. proprietary platforms). Consequently, the study extends current theories on instructional technology by showing that "pedagogical intentionality" is the critical variable, even when utilizing standard digital authoring tools (Maskur et al., 2021; Sandy et al., 2022).

An essential anomaly observed in this study involves the disparity between students who excelled and those who struggled with chart interpretation despite the flipbook's interactive features. While the media was validated as "highly positive," the failure of some students to connect information highlights a structural issue in prior learning experiences: a systemic deficit in foundational visual literacy. This finding contradicts the assumption that digital media automatically flattens learning difficulties; instead, it reveals that digital transformation must be coupled with "metacognitive training" to help students decode visual data (Sibua & Suharna, 2024; Takasihaeng et al., 2021). This provides a significant theoretical contribution, suggesting that instructional transformation is not solely about content delivery but also about the "preparedness" of the learning ecosystem to support diverse cognitive processing styles. This research thus argues that policy-level integration of numeracy in higher education must prioritize the development of digital visual literacy alongside mathematical content, as the former is the prerequisite for the latter in a digital-first pedagogical landscape (Nida et al., 2020; Wicaksono, 2020).

The long-term practical and theoretical implications of this study suggest a move toward "Instructional Pluralism," where numeracy-infused media becomes the standard architecture for disciplinary teaching. Beyond technical proficiency, this research touches upon a deeper instructional philosophy: the transformation of technical expertise into an accessible, inquiry-based language for students. This process mirrors the pedagogical concept of Muraqabah—in an instructional sense—where the media design facilitates a continuous, self-reflective monitoring of the learning process (Suharna et al., 2025). By embedding numeracy into digital formats, we create an environment where learners are empowered to interrogate, synthesize, and apply their knowledge critically. Future institutional policies must therefore invest not only in hardware or software licenses but in the systematic redesign of RPS (Rencana Pembelajaran Semester) to incorporate these evidence-based, numeracy-infused digital frameworks. This transformation is not merely an improvement in technical efficiency; it is an essential evolution of the Scholarship of Teaching and Learning (SoTL), moving the discipline toward a future where technological and pedagogical mastery are indistinguishable in the creation of impactful instructional outcomes (Sandy et al., 2022; Suharna et al., 2025).

## CONCLUSION

### 5.1 Conclusion

1. The development of the numeracy-infused flipbook, structured through the 4-D model, successfully produced a valid, practical, and effective instructional medium tailored to improve undergraduate students' mathematical connection skills.
2. Expert validation from media, subject matter, language, and educational specialists confirmed the media's instructional feasibility, establishing a high standard for its deployment within the university learning ecosystem.

3. Empirical results from the implementation phase demonstrated that 72.22% of the 18 participating students achieved excellent mastery in solving numeracy-based problems, reflecting a substantial improvement in their ability to bridge concepts compared to initial diagnostic assessments.
4. The media achieved a high effectiveness score of 89.77% in student response evaluations, indicating that the interactive features and contextualized examples significantly enhanced learning engagement and conceptual clarity.
5. Qualitative analysis revealed that while students generally thrived, visual literacy remains a critical cognitive dimension that determines the success of digital instructional tools, highlighting the necessity of integrated cognitive scaffolding in future media designs.

### 5.2. Suggestions

Future research should focus on diversifying the instructional dimensions of the flipbook by incorporating more complex, multi-layered problem sets that require interdisciplinary synthesis, such as connecting mathematics with social sciences or environmental studies. It is recommended that subsequent studies expand the sample size and implement a longitudinal tracking system to observe the long-term retention of mathematical connection skills developed through digital platforms. Furthermore, future development should prioritize the integration of adaptive learning features, allowing the flipbook to adjust its difficulty level in real-time based on student performance. Finally, researchers are encouraged to explore the impact of integrating collaborative learning modules within the flipbook environment to foster peer-to-peer cognitive scaffolding, thereby moving toward a more holistic, student-centered digital pedagogy.

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