Flash-Based KWL Interactive Media for TIMSS Oriented Reading Comprehension Skills

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Article Info	ABSTRACT
	Purpose of the study: This study aims to develop and validate Flash-based interactive learning media integrated with the K-W-L strategy to enhance eleventh-grade students' reading comprehension skills and align instructional practices with higher-order cognitive demands reflected in international assessments such as the *Trends in International Mathematics and Science Study* (TIMSS). **Methodology:** This research employed a Research and Development (R&D) design adapted from the Borg and Gall model. The study involved eleventh-grade students in a public senior high school. Data were collected through expert validation sheets, reading comprehension tests (pre-test and post-test), and student response questionnaires. Data analysis included descriptive percentage analysis and N-Gain calculation. **Main Findings:** The developed media achieved an average expert validation score of 88.18%, categorized as good and feasible for classroom implementation. The effectiveness test showed a mean N-Gain score of 0.51, indicating moderate improvement in students' reading comprehension. Significant gains were observed in higher-order indicators, including inference-making, interpretation of implicit meaning, and evaluation of contextual information aligned with TIMSS cognitive demands. **Novelty/Originality of this study:** This study synergises the K-W-L metacognitive strategy systematically within Flash-based interactive media to support analytical reading skills aligned with international assessment competencies. Unlike prior studies focusing solely on strategy use or media feasibility, this research bridges digital instructional design, structured reading strategy, and global literacy challenges in secondary pedagogy.

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1. INTRODUCTION

The development of educational technology has significantly influenced instructional practices in secondary education [1]-[3]. Digital-based learning media are increasingly integrated into classroom instruction to enhance students' engagement, interaction, and conceptual understanding [4]-[6]. However, the effectiveness

of such integration depends not only on technological innovation but also on the instructional strategies embedded within the media [7]. International large-scale assessments, such as the Trends in International Mathematics and Science Study (TIMSS), consistently report that Indonesian students still experience difficulties in solving higher-order thinking problems, particularly those requiring analytical reading, interpretation of information, and reasoning skills [8]-[10]. Although TIMSS primarily assesses mathematics and science, many test items require strong reading comprehension skills to interpret contextual problems accurately [11], [12], [13]. This indicates that students' performance is not solely determined by content knowledge, but also by their ability to understand, analyze, and process written information critically [14], [15], [16].

Reading comprehension, therefore, plays a fundamental role in supporting students' academic achievement across disciplines [17]-[19]. It involves not only recognizing textual information but also constructing meaning, making inferences, and evaluating arguments. In the Indonesian language classroom, reading comprehension instruction often relies on conventional printed texts with limited technological support. Furthermore, instructional practices frequently emphasize content delivery rather than strategic reading processes, which may reduce students' engagement and limit the development of critical literacy skills [20], [21].

One instructional strategy that promotes active and reflective reading is the K-W-L strategy (What I Know, What I Want to Learn, What I Learned). This strategy activates prior knowledge, encourages students to formulate questions before reading, and guides them to reflect on newly acquired information after reading [22]. Previous studies have demonstrated that structured reading strategies can enhance comprehension and critical thinking skills [23]. However, the integration of K-W-L within interactive digital learning media remains limited, particularly at the senior high school level. In addition, research on technology-based learning media in Indonesian language instruction has predominantly focused on product feasibility and visual attractiveness, rather than aligning instructional design with global competency demands reflected in international assessments such as TIMSS [24].

There remains a gap between reading strategy implementation, digital media development, and the cultivation of higher-order cognitive skills required in contemporary education [25]-[27]. To address this gap, this study develops interactive Flash-based learning media for reading comprehension instruction at the eleventh-grade level, integrating the K-W-L strategy into its instructional design [28]. The proposed media aims to provide structured reading guidance, interactive learning experiences, and reflective activities that support analytical and critical thinking steps. The innovation of this research lies in the systematic integration of a metacognitive reading strategy within digital instructional media to support competencies aligned with international assessment demands [29]-[31]. By connecting reading comprehension instruction with broader educational challenges identified in TIMSS, this study contributes to strengthening literacy-based learning design in secondary education [32]. The developed media is expected to serve as an alternative instructional resource that enhances students' engagement, supports strategic reading practices, and potentially reinforces cognitive skills required in solving complex, text-based problems.

Research in previous years showed that the implementation of the KWL strategy was more focused on improving reading comprehension in general without specifically integrating it with international assessment frameworks such as TIMSS [33], while other studies on Flash-based learning media tended to emphasize aspects of product development and media feasibility without in-depth testing of its impact on reading comprehension skills oriented towards higher-order thinking questions [34]. In addition, studies related to TIMSS-based reading skills mostly analyzed students' achievements or difficulties in answering questions, but had not developed interactive media that systematically combined metacognitive strategies such as KWL with question and stimulus designs that were in line with the characteristics of TIMSS [35]. Thus, there has been no research that comprehensively integrates Flash-based interactive media, KWL strategies, and TIMSS orientation in one development framework to improve reading comprehension skills. This gap is the focus of the research entitled Flash-Based KWL Interactive Media For TIMSS Oriented Reading Comprehension Skills, which presents media innovations that are not only technically feasible and interesting, but also pedagogically directed at strengthening students' international standard-based reading comprehension skills and higher-order thinking skills [36], [37], [38].

The strength of this research lies in the harmonisation of the conceptual dimensions and operational practices of KWL metacognitive strategies, Flash-based interactive media, and a TIMSS-oriented assessment framework in one systematic and tested development design [39], [40], [41]. While previous research tends to separate learning strategies, media development, and TIMSS achievement analysis, this research presents a synthesis of all three through media design that explicitly aligns the Know–Want–Learned stages with the characteristics of TIMSS questions and stimuli that require the ability to understand complex information, interpret data, and perform high-level reasoning. Another novelty lies in the design orientation that focuses not only on the feasibility and practicality of the media, but also on the construct validity of reading comprehension skills based on international standards, so that the resulting product is not only technologically innovative but also has a strong pedagogical and assessment foundation [42], [43]. Thus, this research offers a model for developing integrated

learning media, adaptive to the demands of global literacy, and relevant to improving students' readiness to face TIMSS-based international assessments.

The findings of this study carry theoretical, pedagogical, and practical significance in promoting internationally benchmarked literacy competencies [44]. Theoretically, this research advances the integration of the KWL metacognitive strategy with TIMSS-oriented assessment design within a digital interactive media framework, thereby contributing to the conceptual development of globally aligned literacy instruction and higher-order thinking skills enhancement. Pedagogically, the findings provide empirical guidance for teachers in designing reading instruction that moves beyond literal comprehension toward interpretation, analysis, and reasoning processes aligned with international assessment standards, ultimately improving students' readiness to meet global benchmarks. Practically, the developed interactive media can be replicated and adapted across diverse educational contexts with similar characteristics, providing a conceptual basis for curriculum developers and policy makers in formulating technology-integrated instructional innovations that respond to 21st-century competency demands [45], [46]. Therefore, this study supports a shift from conventional reading instruction toward a more strategic, structured, and internationally standardized approach to reading comprehension development.

The urgency of this study is grounded in the persistent gap between students' reading comprehension performance and the competencies required in international large-scale assessments such as TIMSS. Despite ongoing curriculum reforms and the increasing integration of technology in classrooms, many students still demonstrate limited ability to interpret complex texts, analyze information critically, and apply reasoning skills in assessment contexts aligned with global standards. This condition indicates that instructional practices have not yet fully accommodated the demands of higher-order thinking and internationally benchmarked literacy skills [47], [48]. Furthermore, the rapid digital transformation in education necessitates the development of interactive and pedagogically sound learning media that do not merely digitize conventional content, but strategically foster metacognitive engagement and structured comprehension processes. Without targeted instructional innovation that integrates metacognitive strategies, interactive technology, and TIMSS-oriented task characteristics, students may continue to experience difficulties in achieving competitive literacy outcomes at the global level. Therefore, developing Flash-Based KWL Interactive Media for TIMSS-Oriented Reading Comprehension Skills is both timely and essential to address systemic instructional gaps and to enhance students' preparedness for internationally standardized assessments [49].

Based on the identified research gaps, the demonstrated need for pedagogically integrated digital innovation, and the urgency of improving students' TIMSS-aligned reading competencies, this study is positioned to offer a focused and systematic solution through the development of an interactive instructional medium grounded in metacognitive strategy and international assessment standards. The synthesis of Flash-based technology, the KWL framework, and TIMSS-oriented reading task characteristics directly responds to the limitations of previous studies that addressed these components separately. Therefore, the title *Flash-Based KWL Interactive Media for TIMSS-Oriented Reading Comprehension Skills* is formulated to explicitly reflect the core problem, the innovative approach, and the targeted competency domain of the research, ensuring conceptual clarity and alignment between the research background, objectives, and expected contributions.

2. RESEARCH METHOD

2.1. Research Design

This study adopts a Research and Development (R&D) model as its research design aimed at producing and validating interactive Flash-based learning media integrated with the K-W-L strategy for reading comprehension instruction. The R&D approach was selected because this research focused not only on examining learning outcomes but also on systematically developing an instructional product [50]. The development procedure adapted the Borg and Gall model, which consists of systematic stages including needs analysis, product design, validation, revision, and field testing [51]. This model ensures that the developed media meets pedagogical, technical, and content standards before implementation. The research was conducted in a senior high school involving eleventh-grade students. The product developed was interactive reading comprehension media designed to strengthen analytical reading skills aligned with competencies required in international assessments such as TIMSS.

2.2. Research Setting

Research Setting This research was conducted in a public senior high school, involving one class of eleventh-grade students in Indonesian language [52]. The second-grade class was chosen because at this level, students are required to demonstrate high-level reading comprehension skills such as analyzing, interpreting, and evaluating texts competencies that align with the cognitive demands reflected in international assessments such as the Trends in International Mathematics and Science Study (TIMSS). The class was purposively selected based on the availability of technological facilities and the teachers' readiness to implement interactive Flash-based

learning media integrated with the K-W-L strategy. The research was conducted through pre-test, treatment, and post-test sessions in regular classroom learning [53].

2.3. Data Collection Techniques

The data was obtained through using, validation questionnaires (like scale). Second reading comprehension test (pre-test and post-test). Third, student response questionnaires. The validation instrument used a percentage feasibility formula :

$$P \frac{f}{N} x \ 100\% \qquad \qquad \dots(1)$$

Where :
P = percentage score
F = obtained score
N = maximum score

The feasibility criteria were categorized as shown in Table 1.

Table 1. Media Feasibility Criteria

Variable	Category	Percentage (%)
x	Bad	0–59
y	Sufficient	60–74
z	Good	75–100

Learning effectiveness was measured using gain score analysis to determine the improvement in reading comprehension skills before and after treatment.

2.4. Research Instruments

The instruments used in this study consisted of (1) expert validation sheets, (2) reading comprehension test instruments, and (3) student response questionnaires. The expert validation sheets were designed using a Likert scale (1–5) to assess content accuracy, instructional design, language clarity, visual appearance, interactivity, and technical functionality of the Flash-based learning media. The validation involved material experts, media experts, and Indonesian language teachers to ensure content and construct validity. The reading comprehension test was administered as a pre-test and post-test to measure students' improvement after using the developed media. The test items were constructed based on curriculum standards and higher-order thinking indicators, including identifying main ideas, making inferences, analyzing implicit meanings, and evaluating textual information. Several items were designed in contextual formats to reflect cognitive processes similar to those assessed in the *Trends in International Mathematics and Science Study* (TIMSS). The test consisted of multiple-choice and short-answer questions to capture both factual understanding and analytical reasoning skills. The student response questionnaire was used to collect data on students' perceptions of the media's usability, attractiveness, clarity of instruction, and usefulness in supporting reading comprehension. The questionnaire also employed a Likert scale format and was analyzed using descriptive percentage techniques. All instruments were reviewed prior to implementation to ensure clarity, relevance, and alignment with the research objectives.

2.5. Data Analysis Technique

Data analysis consisted of, first descriptive quantitative analysis for validation results. Second, gain score calculation to measure learning improvement, and the last, percentage analysis of student responses. The gain score was calculated using,

$$N - Gain \frac{Posttest - Pretest}{Maximum \ Score - Pretest} \qquad \dots(2)$$

The improvement category was interpreted as follows:
- High (≥ 0.7)
- Medium (0.3–0.69)
- Low (< 0.3)

This analysis was used to determine whether the developed media effectively enhanced reading comprehension skills aligned with higher-order cognitive demands.

3.   RESULTS AND DISCUSSION

This section reports findings related to the design and implementation of Flash-based interactive learning media integrated with the K-W-L approach, followed by a comprehensive discussion linking the results to reading comprehension theory and cognitive demands reflected in international assessments such as the Trends in International Mathematics and Science Study (TIMSS).

3.1. Media Feasibility and Validation Results

The developed learning media underwent expert validation to assess its feasibility in terms of content quality, instructional design, language clarity, visual appearance, and technical functionality. The validation results are presented in Table 2.

Table 2. Expert Validation Results

Aspect Evaluated	Percentage (%)	Category
Content Feasibility	88.4	Good
Instructional Design	85.7	Good
Language Accuracy	90.2	Good
Visual & Media Quality	87.5	Good
Technical Functionality	89.1	Good
Average	88.18	Good

The average validation score reached 88.18%, which falls into the "Good" category. These results indicate that the developed media is pedagogically and technically appropriate for classroom implementation. The integration of the K-W-L stages within the interactive structure was considered systematic and supportive of guided reading processes. The feasibility percentage was calculated using the following formula.

$$P \frac{f}{N} \ x \ 100\% \qquad …(3)$$

Where :
P = percentage score
F = total obtained score
N = Maximum possible score

The high validation score suggests that the product meets instructional quality standards as recommended in educational media development research [54].

3.2. Effectiveness of the Developed Media

To measure instructional effectiveness, pre-test and post-test scores were analyzed using N-Gain calculation. The descriptive results are shown in Table 3.

Table 3. Pre-Test and Post-Test Results

Indicator	Pre-Test	Post-Test	-Gain	Category
Mean Score	2.35	81.47	.51	Medium
Highest Score	8	95		— —
Lowest Score	5	0		— —

The normalized gain (N-Gain) was calculated using:

$$N - Gain \frac{Posttest-Pretest}{Maximum \ Score-Pretest} \qquad …(4)$$

where:
Post = post-test score,
Pre = pre-test score,
Max = maximum possible score.

The mean N-Gain of 0.51 indicates a moderate improvement category, suggesting that the developed media effectively enhanced students' reading comprehension skills.
A closer analysis of item-level performance revealed improvements in higher-order indicators, particularly:

- Making inferences
- Interpreting implicit meaning
- Evaluating arguments in contextual texts

These cognitive processes align with analytical competencies emphasized in TIMSS assessments, where students are required to interpret complex information presented in textual or contextual formats [55].

The findings demonstrate that integrating the K-W-L strategy within interactive digital media significantly improves reading comprehension performance. The structured stages of K-W-L activate prior knowledge (K), stimulate inquiry (W), and reinforce reflection (L), promoting metacognitive engagement during reading. The improvement in inference-making and analytical interpretation indicates that students did not merely recall textual information but engaged in deeper cognitive processing. This supports constructivist learning theory, which emphasizes active knowledge construction [56].

Moreover, the integration of digital interactivity enhanced student motivation and engagement. Observational data showed that students were more attentive and participative compared to conventional reading instruction. Interactive quizzes and reflective prompts embedded in the media encouraged active response rather than passive reception. From a broader perspective, the results are relevant to global educational challenges. TIMSS findings consistently show that Indonesian students face difficulties in solving contextual and reasoning-based problems [57]. Although TIMSS focuses on mathematics and science, the ability to comprehend complex texts directly affects students' performance. Weak reading comprehension limits the ability to interpret problem statements accurately.

Therefore, strengthening reading comprehension through strategic and technology-supported instruction contributes indirectly to improving competencies required in international assessments. The developed media bridges three important elements:

1. Strategic reading instruction (K-W-L)
2. Digital learning innovation
3. Alignment with higher-order cognitive demands

These findings are consistent with previous studies indicating that structured reading strategies improve comprehension and critical thinking skills [58]. However, unlike prior research that examined strategy use in conventional settings, this study integrates the strategy within interactive media, offering a more systematic and engaging instructional model. Despite the moderate N-Gain category, the improvement suggests meaningful pedagogical impact. The results indicate that technology integration alone is insufficient; effectiveness emerges when instructional strategy and digital design are coherently aligned [59]. In summary, the developed Flash-based interactive media integrated with the K-W-L strategy is both feasible and effective in enhancing reading comprehension skills [60]. The improvement in analytical reading abilities suggests potential contribution to strengthening competencies that support performance in text-based reasoning tasks similar to those found in international assessments.

Based on a synthesis of previous research findings from 2021, 2022, and 2024 [60]-[62], a conceptual and empirical gap appears to exist between the application of technology-based learning media and strengthening efforts cognitive strategies in reading instruction. Previous studies generally emphasize the importance of procedurally implementing pre-reading, while-reading, and post-reading stages, but in practice, there are still discrepancies in classroom implementation and a dominance of approaches focused on literal comprehension. Other studies highlight the use of digital media and interactive quiz applications, which have been shown to increase student motivation, engagem

ent, and rapid response, but have not explicitly integrated a systematic metacognitive strategy framework to guide the process of activating prior knowledge, constructing meaning, and reflecting on understanding. Furthermore, Most previous studies have only emphasised improving overall comprehension without in-depth analysis of higher-order thinking indicators such as inference, interpretation of implicit meaning, and evaluation of contextual arguments that align with international assessment requirements[64]. The findings of this study indicate that the development of Flash-based interactive media integrated with the K-W-L strategy not only meets the pedagogical feasibility standards (average validation of 88.18% in the good category), but also results in an increase in reading ability in the moderate category (N-Gain 0.51) with significant improvements in analytical and evaluative thinking aspects. Thus, the main gap lies in the suboptimal integration between interactive technology and explicit reading strategies in previous studies, while this study presents a contribution by integrating both in a structured manner so as to support the improvement of reading skills that are more in-depth and oriented towards high-level cognitive competencies.

The main contribution of this research lies in the development and systematic integration of Flash-based interactive learning media. with the K-W-L metacognitive strategy within a framework for strengthening reading skills oriented to the cognitive demands of international assessments such as the Trends in International Mathematics and Science Study. While previous research tends to separate the use of technology as a motivational tool and reading strategies as stand-alone pedagogical procedures, this study presents a synthesis of both in an integrated instructional design that guides the activation of prior knowledge (Know), exploration of new

information (Want), and reflection on understanding (Learn) in an interactive and structured manner [65]. Another novelty lies in the evaluation focus that not only measures general score improvements but also analyzes improvements in higher-order thinking indicators such as the ability to make inferences, interpret implicit meanings, and evaluate contextual arguments, which have so far been underexplored in reading media development research. Methodologically, this study also strengthens its contribution through comprehensive expert validation covering aspects of content, instructional design, language, visuals, and technical aspects, thus ensuring that the product is not only effective but also meets pedagogical quality standards. Thus, this research offers a reading media development model that is not only technologically innovative, but also responsive to the needs of 21st-century analytical literacy and aligned with global competency standards [66].

The findings of this study provide significant theoretical and practical implications for the development of technology-based reading instruction. Theoretically, the integration of interactive media with the K-W-L strategy reinforces the perspective that improving reading skills is not sufficient only through the presentation of digital materials, but requires structured metacognitive scaffolding to direct students' thinking processes from schemata activation to reflection on meaning [67]. This is relevant to the demands of analytical literacy as measured in international assessments such as the Trends in International Mathematics and Science Study, which emphasizes inferential, interpretative, and evaluative abilities. Practically, the results of the medium N-Gain category (0.51) with an increase in higher-order thinking indicators indicate that this model can be used as an alternative reading instructional design that is more adaptive to the needs of the 21st century. Teachers can utilize the K-W-L structure in an interactive digital format to build engagement while deepening students' cognitive processes, while curriculum developers can use it as a reference in designing strategy-based media that is not only interesting but also has an impact on the quality of in-depth text comprehension [68].

While the current research shows encouraging results, there are a number of methodological limitations that need to be considered. The limited sample size implies caution in generalising the findings, so validation in a broader population is highly recommended. In addition, the evaluation of media effectiveness was conducted over a relatively short period, so it was not able to provide a comprehensive picture of the long-term impact on improving reading skills and the consistency of developing higher-order thinking skills in students. [69]. Third, the utilization of a Flash-based platform has limited technological compatibility with certain devices, potentially impacting the sustainability of implementation across school contexts with varying facilities. Furthermore, this study focused more on the cognitive aspects of reading comprehension and did not in-depth explore affective dimensions such as intrinsic motivation or student self-regulation in media use. Therefore, subsequent research should consider increasing the number of participants.extend the duration of the intervention, and develop a more adaptive platform compatible with current technology.

Overall, the discussion underscores that meaningful improvement in reading comprehension emerges not merely from the adoption of digital tools, but from the deliberate alignment between instructional strategy, cognitive scaffolding, and technological design. By embedding the K-W-L framework into an interactive digital environment, this study demonstrates how structured metacognitive guidance can transform technology from a motivational supplement into a cognitively purposeful learning medium [70]. The convergence of validated instructional quality, measurable gains in higher-order thinking, and alignment with competencies reflected in international assessments such as Trends in International Mathematics and Science Study highlights the broader pedagogical significance of the model [71]. Rather than positioning technology and strategy as separate instructional components, the findings illustrate the importance of integrative design in addressing persistent literacy challenges and advancing students' analytical reading capacities. Consequently, this discussion situates the developed media not only as an instructional product, but as a conceptual model for bridging digital innovation, metacognitive engagement, and global competency standards in contemporary reading education.

4. CONCLUSION

This study resulted in the development and validation of Flash-based KWL interactive media that was proven to meet the eligibility criteria eleventh students, as evidenced by the average expert validation score of 88.18% in the "Good" category. Furthermore, the media demonstrated effectiveness in achieving its primary objective, with the implementation resulting in a mean N-Gain score of 0.51, indicating a moderate yet significant improvement in students' reading abilities. Notably, the gains were most pronounced in higher-order thinking indicators such as making inferences, interpreting implicit meanings, and evaluating arguments, thereby confirming that the media successfully aligns instructional practices with the cognitive demands of international assessments like TIMSS.

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USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declarethat no artificial intelligence (AI) tools were used in the preparation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried outentirely by the authors without the assistance of AI-based technologies.

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