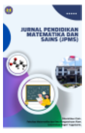

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Hydro Quest as a Construct 2-based Interactive Multimedia for Statics Fluid Learning

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Abstract

This study aimed to develop Hydro Quest, a Construct 2-based interactive multimedia for static fluid learning, and examine its feasibility, practicality, and potential to support students' cognitive achievement. Grounded in Multimedia Learning Theory, constructivist learning principles, and gamification concepts, Hydro Quest integrates concept visualization, simulations, electronic worksheets, game-based formative assessment, and immediate feedback within a single learning environment. This Research and Development study employed the DDD-E model (Decide, Design, Develop, and Evaluate). The participants consisted of five expert validators, two physics teachers, 10 students in a small-scale evaluation, and 36 students in a large-scale evaluation. Data were collected through interviews, questionnaires, validation sheets, and cognitive tests. The media achieved Aiken's V values of 0.86, 0.85, and 0.88 for content, media, and language aspects, respectively. Teacher and student responses ranged from 84.75% to 92.71%, indicating high practicality. Learning outcomes were higher at post-test than at pre-test following the implementation of Hydro Quest, as indicated by a mean n-Gain of 0.67, statistically significant differences as indicated by the Wilcoxon signed-rank test (small-scale: $Z = -2.810$, $p = .005$; large-scale: $Z = -5.241$, $p < .001$), and large effect sizes ($r = 0.889$ and 0.874). These findings indicate that Hydro Quest is a feasible and practical learning medium with the potential to support static fluid learning.

Keywords: *Construct 2, Interactive multimedia, Cognitive learning outcomes, Static fluids*

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INTRODUCTION

Education plays a central role in preparing human resources capable of meeting the demands of the twenty-first century. Along with rapid technological advancement and digitalization across various aspects of society, educational practices have undergone substantial changes, encouraging teachers to integrate digital technology into classroom instruction (Sabri et al., 2026). In this context, learning success is influenced not only by instructional strategies but also by the selection of learning media that are aligned with students' needs and learning characteristics (Pratama & Sari, 2025). Technology-based learning media facilitate access to learning resources, increase student engagement throughout the learning process, and provide more meaningful learning experiences (Clark & Mayer, 2023). Consequently, interactive multimedia has become an increasingly relevant alternative for promoting active, flexible, and student-centered learning.

The use of interactive multimedia is particularly important in physics education because many physical phenomena cannot be observed directly and therefore require visualization and simulation to facilitate students' understanding of abstract concepts (Mayer & Fiorella, 2022). According to Multimedia Learning Theory, learning is more effective when verbal explanations are presented together with relevant visual representations rather than through text alone (Mayer, 2020). Accordingly, learning media function not only as a means of delivering instructional content but also as a tool that encourages students to actively construct their knowledge throughout the learning process (Bond, 2022). Interactive multimedia also helps students understand concepts by presenting information in a clear, systematic, and accessible manner (Arrazi & Diyana, 2024). Previous studies have reported that interactive multimedia contributes positively to students' conceptual understanding and engagement in science learning (Hartanto, 2024). Likewise, Ma'rifah et al. (2023) found that the implementation of interactive multimedia improved students' learning outcomes. These findings indicate that interactive multimedia has considerable potential to facilitate students' understanding of abstract physics concepts.

One physics topic that particularly requires appropriate learning media is static fluids. This topic involves numerous abstract concepts and relationships among physical quantities that are often difficult for students to understand through verbal explanations alone. Ammar et al. (2023) reported that 82.6% of students perceived physics as a difficult subject, 52.2% identified static fluids as one of the most difficult topics, and 93.5% preferred learning media incorporating images, videos, and animations. These findings suggest that students require learning experiences that support concept visualization while facilitating conceptual understanding. Therefore, learning media for static fluids should not merely present information but should also provide visualization, simulation, guided learning activities, and interactive learning experiences.

Several studies have attempted to improve static fluid learning through the development of digital learning media. Ambarsari et al. (2025) reported that audio-visual media contributed positively to students' learning outcomes, whereas Farizi et al. (2022) found that animation-based media enhanced students' engagement and conceptual understanding. In addition, Wiandari et al. (2023) developed problem-based e-modules, while Yuniar et al. (2021) developed guided inquiry-based interactive e-modules for static fluid instruction. Dhanil et al. (2021) also developed cognitive conflict-based interactive multimedia, whereas Sinaga et al. (2023) developed web-based interactive multimedia to support students' conceptual understanding. Overall, these studies demonstrate that digital learning media can improve various aspects of physics learning, including conceptual understanding, learning engagement, inquiry activities, and problem-solving skills.

Despite these contributions, previous studies have generally focused on particular instructional approaches or individual learning components. Some studies emphasized animations and concept visualization, whereas others focused on inquiry activities, cognitive conflict strategies, or web-based learning. As a result, students still rely on different learning resources separately rather than learning through a unified multimedia environment. The integration of concept visualization, interactive simulations, electronic worksheets, game-based formative assessment, and immediate feedback within a single multimedia platform remains limited. This limitation indicates a research gap in the development of interactive multimedia that integrates these instructional components into a comprehensive learning environment supporting concept exploration, assessment, and feedback during static fluid learning.

The research gap identified in previous studies was further supported by the preliminary needs analysis conducted at the research site. Interviews with the physics teacher revealed that classroom instruction was still dominated by direct instruction, whiteboard explanations, and problem-solving exercises, whereas interactive digital media were rarely incorporated into learning activities. The teacher also reported limited time and resources to develop innovative learning media. Meanwhile, interviews with students indicated that they experienced difficulties in solving static fluid problems requiring them to relate several concepts and physical quantities simultaneously. Students also reported that learning supported by visualizations, animations, interactive quizzes, and immediate feedback was easier to understand than learning that relied primarily on formula-based explanations. These findings indicate that students require learning media capable of facilitating concept visualization while providing electronic worksheets, immediate feedback, and meaningful learning experiences.

The development of such multimedia should be grounded in well-established learning theories. Multimedia Learning Theory explains that learning becomes more effective when verbal explanations are combined with relevant visual representations (Mayer, 2020). Constructivist learning theory further emphasizes that students construct knowledge more effectively through active exploration and meaningful learning experiences (Ertmer & Newby, 2013). In addition, gamification can increase students' engagement and persistence through challenges, feedback, and learning progression mechanisms (Christopoulos & Mystakidis, 2023). These theoretical perspectives suggest that effective multimedia should incorporate visualization, exploration, electronic worksheets, assessment, immediate feedback, and motivational elements within a single learning environment.

One platform that supports the development of such multimedia is Construct 2. The platform combines text, images, animations, simulations, interactive exercises, and game-based features within a web-based learning environment. Murdoko et al. (2017) demonstrated that Construct 2 is suitable for developing science learning media, while Septiani and Okmarisa (2023) reported that Construct 2-based learning media were valid and practical for classroom implementation. Nevertheless, most Construct 2-based learning media have been developed for topics other than static fluids or have focused on specific instructional functions rather than integrating multiple learning components within a single multimedia environment.

Based on these considerations, this study developed Hydro Quest, a Construct 2-based interactive multimedia for static fluid learning. Unlike previous studies that generally developed a single type of digital learning media, Hydro Quest combines concept visualization, interactive simulations, electronic worksheets, game-based formative assessment, and immediate feedback within one multimedia environment. This design enables students to study concepts, conduct exploration, complete electronic worksheet activities, and evaluate their understanding through interconnected learning activities without switching between different learning resources. Accordingly, Hydro Quest was developed to address the limitations of previous studies by integrating multiple instructional components into a single learning medium. Therefore, this study aimed to develop and evaluate Hydro Quest by examining its validity, practicality, and potential to support students' cognitive achievement.

METHOD

This study adopted a Research and Development (R&D) using the DDD-E (Decide, Design, Develop, and Evaluate) model proposed by Ivers and Barron (2010). The model was selected because it provides a systematic framework for multimedia development, encompassing needs analysis, instructional design, product development, and product evaluation (Siregar, 2023). Furthermore, the Research and Development approach has been recognized as an appropriate method for designing, validating, and evaluating educational products before their implementation in classroom instruction (Rustamana et al., 2024).

The development of Hydro Quest was guided by Multimedia Learning Theory (Mayer, 2020), constructivist learning principles (Jonassen, 1999), and gamification concepts (Christopoulos & Mystakidis, 2023). These theoretical perspectives informed the integration of visualization, exploration, electronic worksheets, immediate feedback and game elements within the multimedia environment. To evaluate the developed product, this study employed a one-group pre-test post-test design. This design was considered appropriate because the study aimed to obtain preliminary evidence regarding the performance of the developed multimedia and changes in students' cognitive learning outcomes following its implementation (Sukarelawan et al., 2024). Since no comparison group was included, the findings were interpreted as evidence of learning improvement rather than superiority over other instructional approaches.

The participants consisted of five expert validators, two physics teachers, and 11th grade students. The validators included three university lecturers in Physics Education and two senior high school physics teachers. The lecturers possessed expertise in physics education, instructional media development, and learning assessment, while the teachers had experience in physics instruction and the implementation of digital learning media.

A needs analysis questionnaire was administered to 72 students. Product evaluation was conducted in two stages involving 10 students during the small-scale evaluation and 36 students during the large-scale evaluation. Participants were selected using purposive sampling because they had previously studied or were currently studying static fluid concepts.

Participation was voluntary. Permission to conduct the study was obtained from the school administration prior to data collection. All participants were informed about the purpose of the study, and all collected data were analyzed anonymously to ensure participant confidentiality.

The Decide stage involved curriculum analysis, learning outcome analysis, content analysis, and multimedia needs analysis. Teacher interviews and student questionnaires were conducted to identify learning difficulties, instructional practices, technology readiness, and multimedia requirements. The findings served as the basis for determining the instructional content and multimedia features of Hydro Quest.

The Design stage focused on designing the instructional structure, multimedia components, and research instruments. The multimedia was designed based on Multimedia Learning Theory (Mayer, 2020), constructivist learning principles (Jonassen, 1999), and gamification concepts (Christopoulos & Mystakidis, 2023).

The Develop stage involved developing the initial Hydro Quest prototype using Construct 2, followed by validation conducted by content, multimedia, and language experts. Feedback provided by the validators was used to revise and improve the multimedia before its implementation in classroom learning.

The Evaluate stage consisted of teacher evaluation, small-scale testing, product revision, and large-scale testing. Teacher and student response questionnaires were administered to evaluate the practicality of the multimedia, whereas pre-test and post-test scores were used to determine students' cognitive learning outcomes after using Hydro Quest.

Data were collected using both non-test and test instruments. The non-test instruments consisted of teacher interview guidelines, needs analysis questionnaires, expert validation sheets, teacher response questionnaires, and student response questionnaires. The test instrument comprised multiple-choice questions designed to measure students' cognitive learning outcomes on static fluid concepts. Twenty items were initially developed. Following content validation, reliability testing, item difficulty analysis, and discrimination analysis, 15 items that met the predetermined quality criteria were retained for the pre-test and post-test. The blueprint of the cognitive learning outcome test is presented in Table 1.

Table 1. Blueprint of the test instrument

Topic	Indicator	Cognitive Level
Surface tension	Identify the cause of a razor blade floating on the water surface.	C1
Archimedes' principle	Infer the condition of eggs in a fluid based on density differences.	C2
Viscosity	Identify factors affecting fluid viscosity.	C2
Archimedes' law	Identify factors affecting buoyant force.	C2
Hydrostatic pressure	Calculate hydrostatic pressure at a given depth.	C3
Viscosity	Calculate terminal velocity using Stokes' law.	C3
Surface tension	Calculate capillary rise.	C3
Hydrostatic pressure	Analyze the relationship between depth and hydrostatic pressure.	C4
Archimedes' law	Determine the volume of a floating object based on Archimedes' law.	C3
Surface tension	Analyze the effect of surface tension on floating objects.	C4
Hydrostatic pressure	Analyze experimental data on hydrostatic pressure.	C4
Viscosity	Analyze the relationship between viscosity and fluid motion.	C4
Surface tension	Analyze experimental results on surface tension.	C4
Archimedes' law	Evaluate the condition of objects in fluids based on Archimedes' law.	C5
Viscosity	Design an experimental procedure to investigate the effect of viscosity on the terminal velocity of a falling sphere.	C6

Instrument quality was evaluated before implementation. Content validity was examined using the Content Validity Ratio (CVR) and Content Validity Index (CVI), indicating that all retained items satisfied the established validity criteria (Nabil et al., 2022). Reliability analysis using Cronbach's Alpha produced a coefficient of 0.76, indicating high internal consistency. Item difficulty and discrimination analyses further confirmed that the retained items were appropriate for measuring students' cognitive learning outcomes.

Different analytical techniques were employed according to the type of data collected, as summarized in Table 2. Interview data were analyzed descriptively to identify learning conditions and multimedia needs, whereas questionnaire data were analyzed using descriptive statistics and percentage analysis. Multimedia validity was evaluated using Aiken's V coefficient (Aiken, 1985). Aiken's V values greater than 0.80 were categorized as high validity, values between 0.40 and 0.80 as moderate validity, and values below 0.40 as low validity. Instrument reliability was examined using Cronbach's Alpha. Based on the criteria reported by SMF Jugessur (2022), reliability coefficients were interpreted as very high ($\alpha \geq 0.90$), high ($0.70 \leq \alpha < 0.90$), moderate ($0.60 \leq \alpha < 0.70$), low ($0.50 \leq \alpha < 0.60$), and very low ($\alpha < 0.50$).

Table 2. Data analysis procedures

Data	Analysis Technique	Purpose
Interview data	Qualitative descriptive analysis	Identify learning conditions and multimedia needs
Needs analysis questionnaire	Descriptive statistics	Identify students' needs and multimedia requirements
Expert validation	Aiken's V coefficient	Determine the validity of the developed multimedia
Teacher response questionnaire	Percentage analysis	Determine the practicality of the multimedia
Student response questionnaire	Percentage analysis	Determine the practicality of the multimedia
Pre-test and post-test scores	Shapiro–Wilk test	Assess data normality
Pre-test and post-test scores	Wilcoxon signed-rank test	Determine whether there is a significant difference between pre-test and post-test scores
Pre-test and post-test scores	Effect size $r = \frac{\lfloor Z \rfloor}{\sqrt{N}}$	Determine the magnitude of the effect of Hydro Quest on students' cognitive learning outcomes
Pre-test and post-test scores	Normalized gain (n-Gain)	Measure learning improvement

Statistical analyses were performed using SPSS Statistics version 29. Pre-test and post-test scores were first examined using the Shapiro-Wilk test to assess data normality. Because the data did not satisfy the normality assumption, differences between pre-test and post-test scores were analyzed using the Wilcoxon signed-rank test. The magnitude of learning improvement was subsequently determined using Rosenthal's standardized effect size, $r = \frac{\lfloor Z \rfloor}{\sqrt{N}}$ (Rosenthal, 1991). Following Cohen (1988), effect size values of 0.10, 0.30, and 0.50 were interpreted as small, medium, and large effects, respectively. Learning improvement was further described using the normalized gain (n-Gain) proposed by Hake (1998), where values below 0.30 indicate low improvement, values between 0.30 and 0.69 indicate moderate improvement, and values of 0.70 or above indicate high improvement.

RESULT AND DISCUSSION

The needs analysis was conducted through teacher interviews and student questionnaires. The interview results indicated that static fluid topics remained challenging because several concepts, such as hydrostatic pressure, Pascal’s law, Archimedes’ principle, surface tension, capillarity, and viscosity, involve relationships among variables that cannot be directly observed. Physics learning was still dominated by teacher explanations, worksheets, and problem-solving activities. According to the teacher, students frequently experienced difficulties when solving contextual problems that required them to connect multiple concepts simultaneously.

Responses collected from students revealed that students expected multimedia that provided concise explanations, visual representations, simulations, and interactive evaluations. These findings support previous studies indicating that static fluid topics are often perceived as difficult because many phenomena occur abstractly and require visualization to support conceptual understanding (Wiandari et al., 2023). According to Multimedia Learning Theory, visual representations can facilitate learning by helping students organize information, connect verbal explanations with relevant visual models, and construct more coherent mental representations of scientific concepts (Mayer, 2020). In physics learning, visualizations are particularly important because they enable students to observe relationships among variables and processes that cannot be directly seen, such as pressure distribution in fluids and the effects of depth on hydrostatic pressure. Beyond supporting conceptual understanding, visual representations can also assist students in analyzing physical phenomena by identifying patterns, comparing conditions, and interpreting cause-and-effect relationships within a problem situation.

Based on these findings, Hydro Quest was designed as an integrated multimedia learning environment that combines learning materials, instructional videos, interactive simulations, electronic worksheets, and game-based formative assessment within a single platform. The overall structure of Hydro Quest is presented in Figure 1.

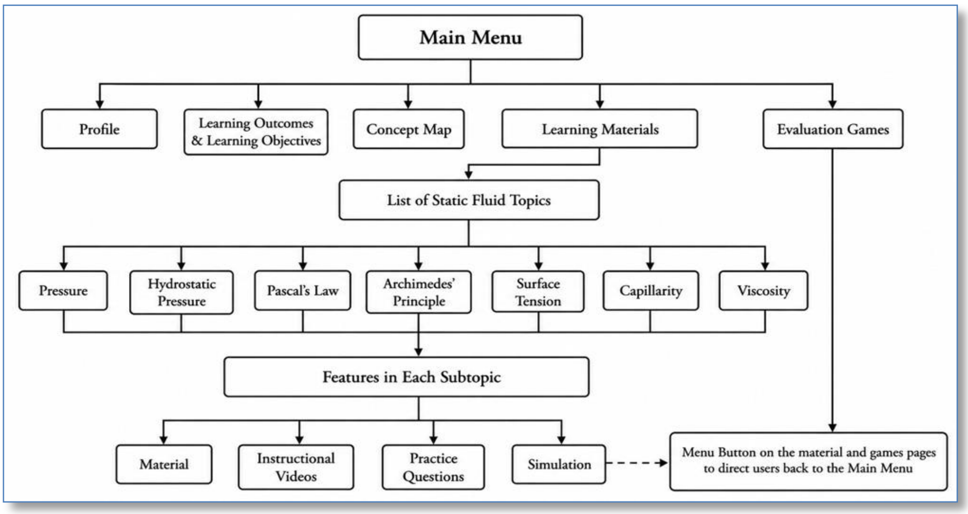


Figure 1. Research flowchart

Construct 2 was selected as the development platform because it supports the integration of text, images, instructional videos, interactive simulations, electronic worksheets, and game elements within a web-based learning environment. This capability enables multiple instructional components to be integrated into a single multimedia platform, allowing students to access all learning resources without switching between different applications. Hydro Quest was developed to provide an integrated learning environment that supports concept visualization, interactive learning, and formative assessment in static fluid instruction.

The design of Hydro Quest was guided by Multimedia Learning Theory (Mayer, 2020), constructivist learning principles (Jonassen, 1999), and gamification concepts (Christopoulos & Mystakidis, 2023). Accordingly, the multimedia structure was organized into interconnected learning components, including learning outcomes and objectives, concept maps, learning materials, interactive simulations, electronic worksheets, and game-based formative assessment. The instructional sequence was designed to guide students progressively from concept introduction to concept application and formative assessment, thereby supporting meaningful learning experiences.

The multimedia format was designed to combine textual explanations, visual illustrations, instructional videos, interactive simulations, electronic worksheets, and game elements within a single learning environment. Interactive simulations were incorporated to facilitate the visualization of static fluid phenomena that are difficult to observe directly during classroom instruction, whereas electronic worksheets were designed to support structured concept exploration. The game-based formative assessment was developed as a board-game activity that provides immediate feedback after each response to reinforce students' conceptual understanding. The incorporation of challenges, rewards, and immediate feedback was intended to enhance students' engagement throughout the learning process. This design is consistent with the principles of game-based learning, which emphasize challenge, feedback, and active participation in supporting learning (Plass et al., 2015). Likewise, Sailer and Homner (2020) reported that game mechanics such as challenges, rewards, feedback, and progression systems can enhance learner participation and motivation.

The initial design of Hydro Quest was refined based on feedback from multimedia, content, and language experts. The revisions included adjusting the size of visual elements, improving the appearance of the multimedia, refining the learning materials, and relating static fluid concepts to everyday phenomena. These revisions were intended to make Hydro Quest more feasible and effective for classroom learning.

The main interfaces of Hydro Quest are presented in Figures 2-5.

Figure 2. Main menu

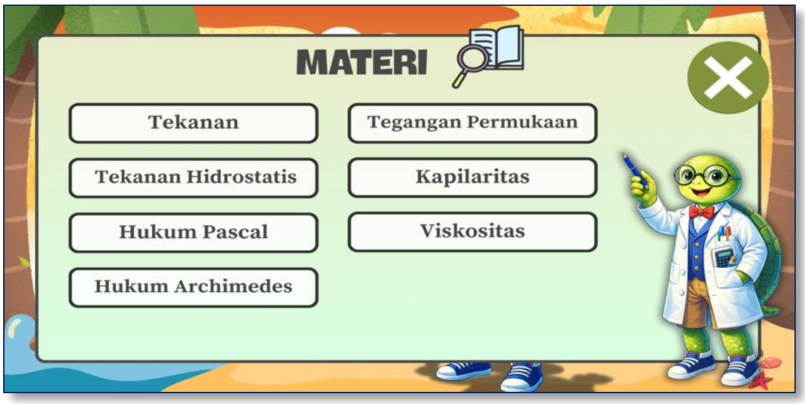
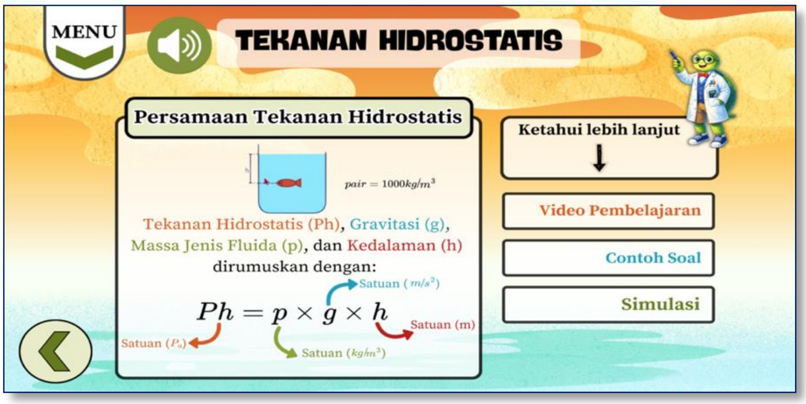


Figure 3. Learning materials menu



$pair = 1000 kg/m^3$

Tekanan Hidrostatis (Ph), Gravitasi (g), Massa Jenis Fluida (p), dan Kedalaman (h) dirumuskan dengan:

$$Ph = p \times g \times h$$

Figure 4. Example of learning and simulation interface

Games Evaluasi berupa boardgames, dimana siswa diminta untuk memainkan sebuah dadu agar player berjalan. Setiap langkah pemain akan muncul soal tantangan yang harus dijawab. Jika siswa mejawab benar maka akan menambah skor, namun jika siswa menjawab salah akan mengurangi nyawa pemain. Games berakhir ketika pemain telah sampai si garis finish. GOOD LUCK !!

Figure 5. Formative assessment game interface

The initial prototype of Hydro Quest was evaluated by three Physics Education lecturers and two senior high school physics teachers. The validation results are presented in Table 3.

Table 3. Validation results

Aspect	Aiken's V	Category
Content Quality	0.88	Very valid
Learning Goal Alignment	0.83	Very valid
Feedback and Adaptation	0.86	Very valid
Motivation	0.86	Very valid
Presentation Design	0.83	Very valid
Interactive Usability	0.85	Very valid
Accessibility	0.86	Very valid
Language	0.88	Very valid

The highest scores were obtained in content quality and language aspects (0.88). This indicates that the material was considered scientifically accurate, consistent with learning objectives, and appropriate for senior high school students. High scores in these aspects are important because conceptual inaccuracies may contribute to misconceptions in physics learning.

Meanwhile, learning goal alignment and presentation design obtained relatively lower scores (0.83). Although still categorized as very valid, these scores suggest that some components required refinement. Validator feedback indicated that several activities could be more explicitly connected to learning objectives and that certain interface elements could be simplified to improve navigation efficiency. Therefore, the validation process provided not only evidence of feasibility but also guidance for product improvement. Language validation also indicated that terminology, sentence structure, and unit notation were appropriate for the target users.

The use of clear scientific language is essential because ambiguous wording may hinder conceptual understanding. The practicality of Hydro Quest was evaluated through teacher and student responses. The results are presented in Table 4.

Table 4. Practicality results

Respondent	Percentage	Category
Teachers	84.75%	Very good
Students (small-scale)	92.71%	Very good
Students (large-scale)	88.94%	Very good

Responses from teachers and students indicate that both teachers and students perceived Hydro Quest positively. Teachers reported that the multimedia was easy to use and aligned with instructional needs, while students appreciated the visual presentation, simulations, and game-based activities. These findings suggest that the multimedia can be implemented in classroom learning with relatively few usability barriers and is acceptable to its intended users.

However, positive responses should be interpreted as evidence of user acceptance and practicality rather than evidence of learning improvement. Response questionnaires primarily measure usability, attractiveness, and user satisfaction. Although students may perceive a product positively because it is visually appealing or engaging, such perceptions do not necessarily reflect gains in conceptual understanding or cognitive learning outcomes.

Therefore, the practicality findings indicate that Hydro Quest can be implemented successfully in classroom learning activities and is perceived positively by users. However, these findings should not be interpreted as evidence of improvements in student learning outcomes. Student learning outcomes before and after using Hydro Quest are presented in Table 5.

Table 5. Mean pre-test, post-test, and normalized gain scores

Evaluation stage	Mean pre-test	Mean post-test	n-Gain	Category
Small-scale	39.00	80.70	0.67	Moderate
Large-scale	32.81	78.47	0.67	Moderate

Results showed that the mean post-test scores were higher than the mean pre-test scores in both evaluation stages. In the small-scale evaluation, the mean score increased from 39.00 to 80.70, whereas in the large-scale evaluation it increased from 32.81 to 78.47. The normalized gain (n-Gain) was 0.67 in both evaluation stages, indicating a moderate level of learning improvement. These findings suggest that students' cognitive learning outcomes improved after learning with Hydro Quest.

This learning improvement may be associated with several features integrated into Hydro Quest, including learning materials, instructional videos, interactive simulations, electronic worksheets, game-based formative assessment, and immediate feedback. Integrating these instructional components helps students visualize abstract concepts and better understand the relationships among concepts in static fluid topics. This interpretation is consistent with the findings of Farizi et al. (2022), who reported that interactive multimedia facilitates students' understanding of abstract physics concepts through visualization and interactive learning experiences. Makransky and Petersen (2021) also emphasized that interactive learning experiences can enhance students' cognitive and affective engagement during learning. Furthermore, Zeng et al. (2024) found that appropriately implemented gamification can positively influence students' engagement and academic performance.

Before hypothesis testing, the pre-test and post-test data were examined for normality using the Shapiro–Wilk test. Because the data were not normally distributed, differences between pre-test and post-test scores were analyzed using the Wilcoxon signed-rank test. Results of the Wilcoxon signed-rank test revealed statistically significant differences between pre-test and post-test scores in both the small-scale evaluation $(Z = -2.810, p = .005)$ and the large-scale evaluation $(Z = -5.241, p < .001)$. These findings indicate that students achieved significantly higher post-test scores after learning with Hydro Quest.

Learning improvement was further examined using the effect size (r) derived from the Wilcoxon signed-rank test. The effect size values were 0.889 for the small-scale evaluation and 0.874 for the large-scale evaluation. According to Cohen (1988), both values represent large effect sizes, suggesting that the implementation of Hydro Quest was associated with substantial improvements in students' cognitive learning outcomes within the study sample. This finding is consistent with previous studies. Sinaga et al. (2023) reported that web-based interactive multimedia enhanced students' conceptual understanding and learning engagement, whereas Aprilia and Romadhon (2025) found that GeoGebra-based interactive media improved students' physics learning outcomes through interactive visualization and learning activities.

The moderate n-Gain values and the large effect sizes should be interpreted as complementary rather than contradictory indicators. While the n-Gain reflects the proportion of learning improvement relative to the maximum attainable score, the effect size indicates the magnitude of the difference between pre-test and post-test scores. Together, these findings suggest that the implementation of Hydro Quest contributed to meaningful improvements in students' cognitive learning outcomes. Nevertheless, because this study employed a one-group pre-test–post-test design without a comparison group, the findings should be interpreted as evidence of learning improvement following the implementation of Hydro Quest rather than conclusive evidence that Hydro Quest is superior to other instructional approaches.

CONCLUSION

This study developed Hydro Quest, a Construct 2-based interactive multimedia for static fluid learning, and showed that the multimedia is valid, practical, and has the potential to support improvements in students' cognitive learning outcomes following its implementation. The findings provide empirical support for integrating Multimedia Learning Theory, constructivist learning principles, and gamification within a single multimedia learning environment by combining learning materials, interactive simulations, electronic worksheets, immediate feedback, and game-based formative assessment. These integrated features may facilitate meaningful learning experiences and promote students' engagement with abstract physics concepts. Nevertheless, because this study employed a one-group pre-test–post-test design without a comparison group and involved participants from a single school, the findings should be interpreted as evidence of learning improvement following the implementation of Hydro Quest rather than conclusive evidence of its superiority over other instructional approaches. Future studies are recommended to employ experimental or quasi-experimental designs with comparison groups, involve larger and more diverse samples, and examine the long-term effects of Hydro Quest on students' conceptual understanding, learning motivation, engagement, and higher-order thinking skills.

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