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Bridging the Cognitive Gap in Inclusive Physics Classes: Behavioral and Cognitive Responses of a Student with Intellectual Disabilities Characteristics to IT-Based Hybrid Flashcards

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ABSTRACT

Objective: *This study aims to develop and evaluate the feasibility of an information technology (IT)-based hybrid flashcard integrated with QR codes for teaching abstract physics concepts, specifically logic gates, in an inclusive classroom.* ***Method:*** *A convergent mixed-methods design was employed involving 14 regular students and one student with intellectual disabilities (Subject I). Quantitative data were collected through pre-tests, post-tests, and observation sheets, while qualitative data were obtained from classroom observations, interviews, and field notes. Quantitative data were analyzed descriptively, whereas qualitative data were analyzed through data condensation, data display, conclusion drawing, and source triangulation.* ***Results:*** *The developed media achieved a practicality score of 94% based on peer observations. Regular students demonstrated moderate conceptual improvement with an average N-Gain score of 0.55. Although Subject I showed lower post-test performance, qualitative findings indicated active participation and successful completion of learning activities with teacher guidance, suggesting that the media supported accessibility and engagement during learning.* ***Novelty:*** *Unlike previous studies that primarily investigated assistive technology in either regular or special education settings, this study provides preliminary evidence for implementing a physical-digital hybrid learning medium within a heterogeneous inclusive classroom, where one instructional medium simultaneously supports regular students and a student with intellectual disabilities despite limited availability of Special Education Teachers (SETs).*

INTRODUCTION

Physics is a strategic field of study designed to develop logical thinking skills through the scientific method (Ardianti et al., 2025). Through physics, students are trained to discover new things and solve problems scientifically (Widhi et al., 2021). However, in reality, physics is often perceived as a daunting subject due to the limited variety of teaching aids and learning materials in the classroom, which results in low student motivation (Ardianti et al., 2025). This situation directly impacts students' low motivation and interest in learning in the classroom.

The complexity of this learning process is further heightened in inclusive classrooms that integrate regular students with students with special needs who have intellectual disabilities. Although inclusive education aims to provide equitable learning opportunities for all learners, students with intellectual disabilities often require specialized instructional support and evidence-based interventions to participate meaningfully in general education settings (Kim et al., 2025). Furthermore, the implementation of inclusive education for students with intellectual disabilities remains challenging because their unique cognitive, social, and adaptive learning needs are not always adequately addressed through conventional instructional approaches (Hornby

& Kauffman, 2024). This inclusive setting is observed at State Islamic Senior High School 2 Gresik. Based on observations of School Field Introduction (PLP) activities and confirmation from subject teachers, there is a student in the physics class who exhibits characteristics of intellectual disability, although they have not yet undergone a formal clinical assessment. Therefore, Subject I was not clinically classified as having an intellectual disability. Instead, the participant was included based on prolonged classroom observations conducted by the physics teacher and confirmed during the School Field Introduction (PLP), which consistently indicated learning characteristics commonly associated with intellectual disability, including substantially lower academic achievement, dependence on teacher guidance, and difficulties participating independently in collaborative learning activities. Children with intellectual disabilities have intellectual abilities below average, which impacts their cognitive abilities and academic achievement (Munandar et al., 2021). These characteristics indicate the need for adaptive learning approaches that can accommodate diverse learning needs and facilitate meaningful participation in classroom activities. Recent studies have highlighted that students with disabilities often encounter barriers in accessing STEM learning opportunities and therefore require accessible learning resources, differentiated instruction, and supportive educational technologies to enhance learning engagement and achievement (Ayeni et al., 2024; Ata-Aktürk et al., 2025). Without the support of contextual adaptive media, their learning potential will be hindered (Limas et al., 2024).

The use of interactive media based on Information Technology (IT) has been shown to have strong potential for enhancing the cognitive abilities of children with intellectual disabilities (Maulidiyah, 2020). Integrating IT into learning can utilize immersive technology, educational videos, and the use of Quick Response Codes (QR-Codes) to stimulate multisensory engagement. Research on multimedia learning suggests that meaningful learning occurs when learners actively process information through the integration of verbal and visual representations, enabling them to select, organize, and connect new knowledge more effectively (Mayer, 2024). Furthermore, multimedia-based learning environments and technology-enhanced instruction can increase interactivity and support the understanding of complex concepts through visual and experiential learning approaches (Çeken & Taşkın, 2022). Learning becomes more meaningful when students are actively engaged through direct experiences (Mana, 2025). Consequently, this can reduce the abstract nature of the material for children with intellectual disabilities. This digital content can be presented in a hybrid format using flashcards—physical cards featuring images or symbols that simplify concepts. By scanning the QR code on the back of the card, students' devices can instantly display an animated video, which has been shown to enhance learning engagement (Sumatraputra et al., 2023). In addition, multimedia lessons that combine narration, animation, and visual representations have been found to facilitate active cognitive processing and improve learning effectiveness (Cavanagh & Kiersch, 2023).

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Furthermore, this technology enables teachers to design flexible materials tailored to individual needs, making it highly relevant for implementation in inclusive classroom settings (Mar'atullatifah et al., 2024). The use of assistive and digital technologies has also been reported to improve accessibility, participation, and inclusion for students with disabilities in educational environments (Fernández-Batanero et al., 2022).

In addition to the Cognitive Theory of Multimedia Learning (Mayer, 2024), the present study is also supported by Cognitive Load Theory, which emphasizes minimizing unnecessary cognitive processing to optimize learners' limited working memory (Sweller, 2024). Furthermore, the Universal Design for Learning (UDL) framework highlights the importance of providing multiple means of representation and engagement to accommodate learner diversity within inclusive classrooms. Collectively, these theoretical perspectives provide a strong rationale for integrating printed flashcards with QR-code-based multimedia in physics instruction.

In line with this, several previous studies have implemented the integration of QR codes into learning card media. Surbakti et al. (2025) used QR code-enabled flashcards, which received a high level of response and enthusiasm from both teachers and students. In line with Sholeh's (2023) findings, the developed media increased learning outcomes by 76%, with students successfully achieving the Minimum Passing Score (MPS), and the media's validity rate reaching 86%. Meanwhile, research in the field of students with special needs indicates that flashcards effectively improve science learning outcomes among students with intellectual disabilities (Lestari, 2023). Furthermore, the development of IT-based media for students with intellectual disabilities by Munandar et al. (2021) successfully improved cognitive abilities, as evidenced by an increase in post-test scores and a media usability score of 82%. However, the majority of these studies still examine the application of media for regular students and those with special needs separately (in segregated settings). Recent studies have emphasized that effective inclusive education requires intentional instructional design, adaptive learning environments, and meaningful participation for diverse learners (Wade et al., 2023). In addition, multimedia characteristics and classroom learning environments have been identified as important factors influencing students' perceptions of inclusion and engagement in inclusive settings (Shane-Simpson et al., 2024). There is a lack of research highlighting the simultaneous application of hybrid physical-digital media within regular inclusive classrooms without a Special Education Teacher (SET), even though collaboration between general educators and special educators is often considered a key factor in successful inclusive practices (Paulsrud & Nilholm, 2023), such as the challenging situation at State Islamic Senior High School 2 Gresik. Most previous studies evaluated instructional media either in regular classrooms or in segregated special education settings. Consequently, limited evidence is available regarding instructional media that simultaneously support regular students and students with intellectual disability characteristics within the same heterogeneous classroom. This study addresses that gap.

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To bridge this gap, logic gate material was selected because of its nature, which requires logical reasoning but is often considered abstract, thus necessitating concrete visualization so that the working principles of digital logic can be easily understood. Therefore, this study focuses on the development of physical flashcard learning media based on Information Technology (IT) with QR-Code integration for logic gate material in inclusive classrooms. This innovation is expected to provide a visual, tactile, and concrete learning experience for inclusive classrooms, thereby creating a learning process that is enjoyable, mindful, and meaningful (meaningful learning), as a core pillar of the deep learning approach. The primary objective of this study is to describe the development process and test the feasibility of this medium when implemented in a heterogeneous classroom ecosystem to provide preliminary evidence regarding the feasibility and potential usefulness of IT-based hybrid flashcards for inclusive physics instruction. Specifically, this study aims to answer the following research questions: (1) What is the process of developing Information Technology (IT)-based flashcard media for teaching logic gates in an inclusive classroom?; and (2) What is the level of suitability of the Information Technology (IT)-based flashcard media for teaching logic gates based on expert evaluation and user feedback?

RESEARCH METHOD

Research Design

This study employed a development research approach using a convergent mixed-methods design, in which quantitative and qualitative data were collected simultaneously and integrated during interpretation. This design was used to evaluate both the feasibility of the developed instructional media and its impact on student learning outcomes and classroom engagement (Taherdoost, 2022; Younas et al., 2025). The development of instructional media followed the ADDIE instructional design model (Analysis, Design, Development, Implementation, and Evaluation), which provides a systematic framework for designing, producing, and evaluating educational products. Mixed-methods approaches have also been widely applied in feasibility studies to evaluate both quantitative outcomes and participant experiences simultaneously, enabling a more comprehensive assessment of educational interventions (George et al., 2023).

Participants and Research Setting

The study was conducted in an inclusive Grade XII Physics classroom at State Islamic Senior High School 2 Gresik, East Java, Indonesia. The classroom consisted of 15 students aged 17–18 years, comprising 14 regular students and 1 student with learning difficulty characteristics (referred to as Subject I). Subject I was not clinically diagnosed through formal psychological assessment. Instead, identification was based on long-term classroom observation by the physics teacher and confirmation during School Field Introduction (PLP) activities, which indicated consistent learning difficulties such as: 1.) lower academic performance compared to peers; 2.) reliance on teacher prompting during learning tasks; 3.) difficulty in independent participation during group activities. For ethical reasons, anonymity was maintained by using the pseudonym "Subject I".

Data Collection Techniques

Data were collected using both quantitative and qualitative instruments. Quantitative data were obtained from: 1.) pre-test and post-test scores to measure cognitive learning outcomes; 2.) student response questionnaires to measure media feasibility and usability; and 3.) observation sheets completed by two independent peer observers. Meanwhile, qualitative data were extracted from several sources, including: 1.) classroom field notes collected during implementation; 2.) semi-structured interviews with the physics teacher and Subject I using an adapted questioning format; and 3.) student learning artifacts such as worksheets, truth tables, and reflection notes.

Development Procedure (ADDIE Model)

Analysis Stage

This stage involved several key operational activities, namely: 1.) classroom observation in inclusive physics learning activities; 2.) informal interviews with the physics teacher; 3.) identification of learning difficulties in logic gate topics; and 4.) analysis of student heterogeneity, particularly focusing on differences in cognitive processing between regular students and Subject I. The results indicated that logic gate concepts were perceived as abstract and difficult, especially for learners requiring concrete visualization and step-by-step scaffolding.

Design Stage

In this stage, the instructional media was designed as hybrid flashcards, which consisted of printed flashcards containing: 1.) concise concept explanations; 2.) logic gate symbols for AND, OR, NOT, NAND, and NOR operations; 3.) truth tables; and 4.) supporting illustrations. It also integrated QR codes linking to multimedia explanations. Furthermore, the design specifications explicitly included: 1.) readability optimization through font size and spacing adjustments; 2.) color contrast for visual clarity; 3.) simplification of language for accessibility; and 4.) structural alignment between visual content and QR-based multimedia. The learning videos linked via QR codes were structured using short explanations, animations, and narration to reduce cognitive load.

Development Stage

The instructional media was developed using several functional tools, which included: 1.) Canva for designing flashcard layouts; 2.) YouTube for hosting instructional videos; and 3.) the ME-QR platform for generating QR codes linking each card to corresponding videos. Each flashcard was embedded with a unique QR code directing students directly to: 1.) concept explanation videos; 2.) animated logic gate simulations; and 3.) step-by-step problem demonstrations.

Expert Validation

The developed media was validated by three experts in physics education andinstructional media. Validation focused on: content accuracy, instructional design quality, visual communication effectiveness, and suitability for inclusive learning contexts. Revisions were made based on expert feedback prior to classroom implementation.

Implementation Stage

The validated media was implemented in a single learning session on the topic of logic gates. The learning procedure included several sequential steps, consisting of: 1.) introduction of flashcards in group settings; 2.) student interaction with printed cards; 3.) QR code scanning using personal smartphones; 4.) collaborative discussion between students; and 5.) teacher scaffolding for clarification and guidance. During implementation, specific classroom dynamics were observed, where: 1.) regular students acted as peer-support learners; and 2.) Subject I engaged through guided interaction and visual-audio support.

Evaluation Stage

Evaluation was conducted using both quantitative and qualitative approaches. Quantitative evaluation included: 1.) pre-test and post-test comparison; 2.) Normalized Gain (N-Gain) analysis for regular students; 3.) descriptive score analysis for Subject I; and 4.) practicality percentage derived from observer sheets. Meanwhile, qualitative evaluation comprised: 1.) classroom observation analysis; 2.) interview transcript analysis; and 3.) student worksheet analysis.

Data Analysis

Quantitative Data Analysis

Quantitative data were obtained from student response questionnaires and pretest and posttest scores. Student responses were calculated as percentages using the following scoring formula (Lestari & Istihapsari, 2026):

$$P = \frac{f}{n} \times 100\% \quad ..(1)$$

Where P represents the percentage score, f is the total score obtained, and n is the maximum score. The percentage result is then converted into objective validity/practicality criteria according to the criteria in Table 1 (Nasrullah & Hidayatullah, 2024).

Table 1. Media Feasibility Criteria Intervals

Criteria Interval (in %)	Criteria
81% < Percentage Score < 100%	Highly Feasible
61% < Percentage Score < 80%	Suitable
41% < Percentage Score < 60%	Fairly Acceptable
21% < Percentage Score < 40%	Unacceptable
Percentage Score < 20%	Very Unacceptable

The effectiveness of the media was analyzed using quantitative descriptive methods by calculating the percentage of classical learning achievement among regular students using the following formula:

$$Final\ Score = \frac{Achieved\ Score}{Maximum\ Score} \times 100\% \quad ..(2)$$

The media is considered to have limited effectiveness if there is an upward trend in the average score from the pre-test to the post-test and the majority of regular class students are able to pass the Minimum Passing Criteria threshold applicable at the school. This study deliberately did not apply inferential statistics because it focused entirely on testing the clinical readability of the product in a single class.

Qualitative Data Analysis

Qualitative data derived from field notes, transcripts of interviews with teachers, and verbatim accounts of interviews with students with intellectual disabilities were analyzed using a circular, iterative approach based on the model proposed by Miles, Huberman, and Saldana (2014), which comprises three stages: data condensation, data display, and conclusion drawing or verification. To ensure the validity and objectivity of the qualitative data, data verification was conducted through source triangulation, which involves comparing the consistency of cross-referenced information between the observer’s findings, the teachers’ subjective accounts, the students’ verbal responses, and the authentic assessment scores of student learning outcomes (Sarhindi et al., 2025). Triangulation was applied to corroborate findings obtained from multiple data sources, thereby minimizing bias and improving the credibility of the qualitative interpretation (Donkoh & Mensah, 2023). Furthermore, the trustworthiness of qualitative research can be strengthened through strategies that support credibility, dependability, transferability, and confirmability of findings (Kakar et al., 2023). Interview transcripts and field notes were manually coded through repeated reading before being grouped into emerging categories. Data credibility was strengthened through source triangulation by comparing classroom observations, interview findings, field notes, teacher confirmation, and students' learning outcomes.

Triangulation Strategy

To ensure validity and trustworthiness, data source triangulation was employed by comparing multiple data sources, consisting of: 1.) classroom observation notes recorded by the researcher; 2.) teacher interview data; 3.) student interview responses, including those from Subject I; 4.) student worksheets and test results; and 5.) observer rating sheets. Triangulation was systematically conducted through: 1.) cross-checking consistency of behavioral observations across observers; 2.) comparing verbal responses with actual task performance; and 3.) validating teacher interpretations with student artifacts. Additionally, peer debriefing was conducted with fellow researchers to reduce interpretation bias and improve analytical rigor.

RESULTS AND DISCUSSION

Results

Cognitive effectiveness was measured using a pre-test and post-test design. The group of regular students (N=14) was given a test comprising 10 questions on the five types of logic gates (AND, OR, NOT, NAND, NOR), each with five multiple-choice options. Meanwhile, students with intellectual disabilities (Subject I) were given an adapted instrument consisting of 3 basic logic gates (AND, OR, NOT) with 3 multiple-choice options. The pre-test and post-test instruments were designed to be different yet equivalent for both regular students and those with intellectual disabilities. The data on the pre-test and post-test results, the average Normalized Gain (N-Gain) scores for the regular group, and the descriptive achievement results for Subject I are summarized in Table 2.

Table 2. Summary of Pre-test, Post-test, and N-Gain Result for Student

Student Group	Number of Student (N)	Pre-test	Post-test	N-Gain	Category/ Description
Regular/typical	14	20.71	64.29	0.55	Moderate
With Intellectual Dissabilities (Subject I)	1	100	60	-	Descriptive

Discussion

The findings of this study can be interpreted through an integrated theoretical framework combining Cognitive Theory of Multimedia Learning (Mayer), Cognitive Load Theory (Sweller), and Universal Design for Learning (CAST). Multimedia integration in IT-based flashcards facilitates dual-channel processing, reduces extraneous cognitive load, and provides multiple means of representation for diverse learners. In inclusive classrooms, this combination is particularly important as learners exhibit heterogeneous cognitive capacities, requiring adaptive instructional design that balances visual, auditory, and tactile modalities.

Analysis of Cognitive Achievement Across Multiple Presentations

Data comparing the cognitive achievement scores of the two sample groups are presented in Figure 1.

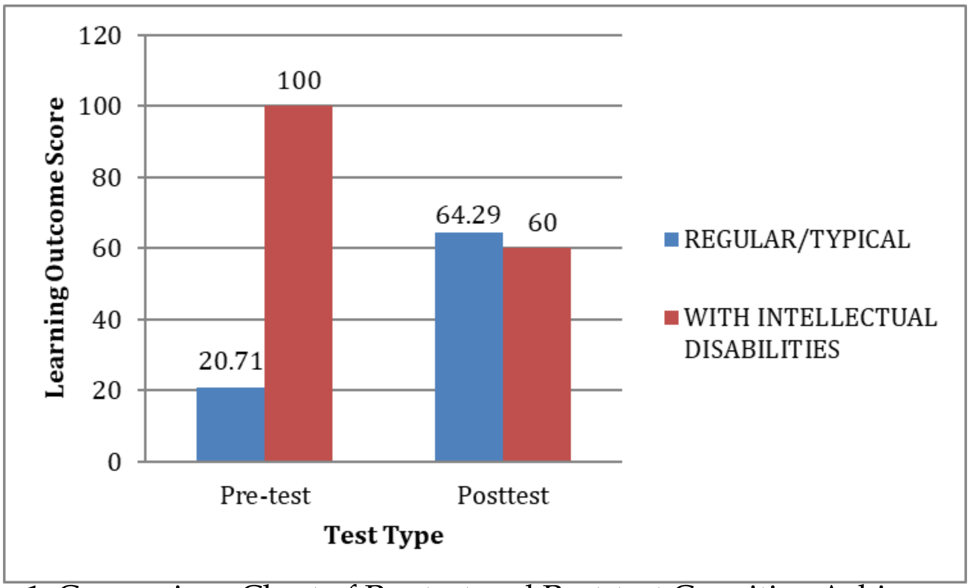


Figure 1. Comparison Chart of Pre-test and Post-test Cognitive Achievement

Based on Figure 1, the regular student group experienced an increase in average scores from 20.71 to 64.29, with an average Normalized Gain (N-Gain) score of 0.55 (Moderate Category) and a classical mastery rate of 64% (9 out of 14 students achieved mastery). These findings are consistent with previous studies reporting that technology-enhanced and interactive learning media can improve students' learning outcomes, engagement, and problem-solving abilities through more meaningful learning experiences. Interactive digital media facilitate active participation and support the development of 21st-century skills, which ultimately contribute to improved academic performance (Daryanes et al., 2023; Kalyani, 2024). Furthermore, educational technology provides opportunities for more student-centered learning and increases learners' motivation and accessibility to information, which positively influences learning achievement (Chugh et al., 2023; Granić, 2022). These findings demonstrate that IT-based media interventions, such as videos and interactive animations, can significantly enhance typical students' conceptual understanding and assist them in solving complex digital logic problems (Sarhindi et al., 2025). The use of these visual media successfully bridges the communication of abstract reasoning, which has long been a daunting challenge in Physics lessons (Sitepu, 2022; Hartuti, 2015).

This result aligns with the Cognitive Theory of Multimedia Learning, which explains that learning becomes more effective when information is presented through the integration of verbal and visual representations. Multimedia-based instruction helps learners organize information more efficiently and reduces the difficulty of understanding abstract concepts, particularly when supported by interactive and well-structured digital content. The implementation of educational technology therefore plays an important role in enhancing comprehension and knowledge acquisition (Mayer, 2024; Chugh et al., 2023). The persistent error pattern in NOR gate reasoning suggests incomplete schema integration between OR operation and NOT negation.

Rather than indicating a lack of exposure, this reflects partial conceptual assimilation, where learners successfully construct foundational logic operations but struggle with hierarchical transformation of logical operators.

Conversely, Subject I (a student with intellectual disabilities) showed a contradictory trend of declining quantitative scores, where their test scores shifted downward from a perfect score of 100 on the pre-test to 60 on the post-test. The decline in Subject I's post-test score may be associated with cognitive fatigue, attention limitations, dependence on teacher prompting during the pre-test, and the limited capacity of working memory commonly reported among learners with intellectual disability characteristics. However, the interpretation of the pre-test score (100) should be approached with caution, as the assessment was conducted under assisted reading conditions. In such contexts, responses may be influenced by immediate auditory cues and examiner prompting rather than fully independent conceptual understanding. Therefore, the pre-test score may not fully represent Subject I’s actual baseline competence in logic gate concepts. The unexpectedly high pre-test score of Subject I should be interpreted cautiously, as it may have been influenced by response bias during assisted reading conditions. In structured assessments where questions are read aloud, learners with intellectual disabilities may rely on prosodic cues or immediate auditory impressions rather than fully processed conceptual understanding. Therefore, this result does not necessarily reflect stable cognitive acquisition but rather situational response patterns under guided conditions. Therefore, the observed score reduction should be interpreted cautiously rather than regarded as evidence of ineffective instructional media. The perfect score of 100 on the pre-test does not reflect Subject I’s true competence, given that digital technology material had never been taught and the majority of regular students also failed the initial test. This perfect score was obtained because the researcher applied a method of direct question reading (assisted assessment).

In a state of empty short-term memory, children with intellectual disabilities tend to provide spontaneous responses based on the intonation of the last sound or the most familiar word they heard from the test reader to please the examiner. To ensure transparency, minimize assessment bias, and support the credibility of these qualitative interpretations, the core themes derived from classroom observations and post-lesson interviews with both the physics teacher and Subject I are summarized in Table 4.

Table 4. Qualitative Excerpts from Teacher and Subject I Interviews

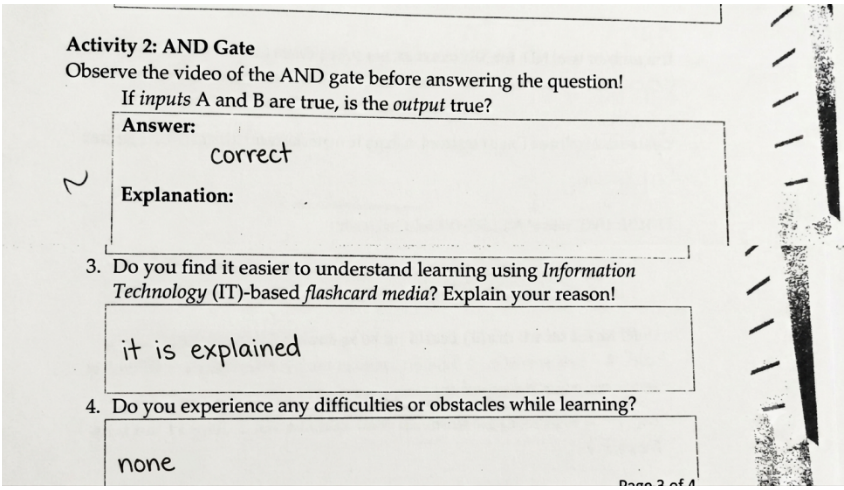
Data Source	**Theme/Category**	**Core Interview Excerpt (English Translation)**
Classroom Teacher	Behavioral Engagement & Motivation	“The implementation was good; the media successfully made the students enthusiastic and interested in learning... The special needs student also looked very enthusiastic.”

Data Source	**Theme/Category**	**Core Interview Excerpt (English Translation)**
	Pedagogical Feasibility in Inclusive Settings	"This media is highly suitable for inclusive education because special needs students need to touch and manipulate concrete, physical objects rather than just listening to passive lectures."
	Media Advantages & Constraints	"The advantage is that it perfectly blends physical and digital elements. However, the teacher (researcher) needed to provide more detailed explanations and active feedback during class classical sessions."
Subject I	Affective Response & Retention	Question: "Did you enjoy learning with the IT-based hybrid flashcards? What logic gates do you remember?" Response: "Yes, I enjoyed it. I remember OR and AND."
	Cognitive Hurdles & Preferences	Question: "Did the animations help you understand the abstract concepts independently?" Response: "No, the logic gate principles were still too difficult. I prefer to have the concepts explained directly and explicitly by the teacher."

The qualitative evidence in Table 4 reveals a critical dichotomy between Subject I's high affective/behavioral engagement and his persistent cognitive hurdles. While the physical-digital integration of the hybrid flashcards successfully stimulated sensory motivation and basic recall (retaining 'AND' and 'OR' gates), the underlying abstract principles remained inaccessible without direct scaffolding. This difficulty underscores the working memory limitations central to Cognitive Load Theory (Sweller, 2024). For students with intellectual disability characteristics, multimedia representations reduce extraneous load but cannot entirely replace explicit, direct teacher instruction, which explains Subject I's explicitly stated preference for live, step-by-step teacher explanations.

Mental Fatigue and Attention Limitations: Learning logic gates demands high levels of logical and analytical thinking (Amalissholeh et al., 2023). Differences in working-memory capacity influence how learners process instructional materials and respond to educational interventions. From a Cognitive Load Theory perspective, the observed decline in performance may also be attributed to increased extraneous cognitive load induced by simultaneous task demands. During the learning process, Subject I was required to process visual information from flashcards, perform motor actions in handling learning materials, and access audiovisual content through QR codes. This multi-channel interaction, while designed to support multimodal learning, may inadvertently increase cognitive load for learners with limited working memory capacity, thereby affecting post-test performance. Students with lower working-memory capacity are more susceptible to distraction, cognitive overload, and difficulties maintaining attention during complex learning activities, which may affect performance on subsequent assessments (Sana & Fenesi, 2025). According to Cognitive Load Theory, learners process new information through a limited-capacity working memory before it can be stored in long-term memory. When instructional tasks require simultaneous processing of multiple interacting elements, cognitive load increases substantially and may reduce learning efficiency, particularly among learners with limited prior knowledge (Sweller, 2024).

During the learning process, Subject I had to engage in layered activities (mental processing combined with manual tasks of holding cards and scanning a device) that drained their brain energy. Since children with intellectual disabilities have a short attention span and are easily distracted (Hallahan & Kauffman, 2021), this intensive multimedia intervention triggered mental fatigue by the end of the session. Consequently, when the post-test was read aloud, Subject I’s auditory focus declined, causing them to miss one answer (2 out of 5 questions incorrect, resulting in a score of 60). Furthermore, since this study was conducted during Ramadan, students’ focus was more easily distracted by other matters throughout the process. Nevertheless, authentic data on the Student Worksheet showed that Subject I was able to complete the task of filling in the truth table independently with handwritten notes accurately, as shown in Figure 2.



Activity 2: AND Gate
Observe the video of the AND gate before answering the question!
If *inputs* A and B are true, is the *output* true?

Answer:
correct

Explanation:

3. Do you find it easier to understand learning using *Information Technology* (IT)-based *flashcard media*? Explain your reason!

it is explained

4. Do you experience any difficulties or obstacles while learning?

none

Figure 2. Results of Learning Activities (top) and Results of Learning Reflection Activities (bottom) for Students with Intellectual Disabilities

Subject I was able to answer the questions provided, albeit using fairly simple language that went straight to the point (without explanation). Although quantitative test scores did not show improvement, the learning process data demonstrated meaningful engagement and task completion. This finding supports the view that technology-assisted learning should not be evaluated solely through achievement scores but also through students' participation, accessibility, and opportunities to engage with learning activities according to their abilities (Granić, 2022; Chugh et al., 2023). Therefore, achievement scores should not be interpreted as the sole indicator of learning success among students with intellectual disability. Previous studies have shown that technology-supported interventions may improve participation, communication, adaptive behavior, and functional task completion even when gains in conventional academic assessments are limited (Montoya-Rodríguez et al., 2022). This demonstrates that the developed media successfully translated abstract concepts into meaningful, concrete understanding for children with special needs, consistent with Dale's Cone of Experience, which places visual media at the level of concrete experience (Mana, 2025; Prasetyo, 1998). Similar findings have been reported in technology-assisted interventions for individuals with intellectual disability, where digital environments provide concrete representations, increase motivation, strengthen attention, and support the development of adaptive skills. The use of technology-mediated learning environments may therefore facilitate understanding among learners who experience difficulties in processing abstract information (Montoya-Rodríguez et al., 2022). Based on the reflective data, the absence of learning barriers among students was attributed to the direct instructional guidance provided by the teacher during media use. This result supports Layachi and Pitchford's (2025) argument that educational technology should complement rather than replace teachers, as teacher guidance remains essential for maintaining engagement, providing scaffolding, and adapting learning experiences to individual learner needs. This indicates that learning success in inclusive education should be interpreted through multiple indicators beyond cognitive test scores, including participation, task completion, and engagement. Standardized assessments alone may not fully capture learning progress in students with intellectual disabilities due to their reliance on contextual support and scaffolding during learning activities.

This demonstrates that personal interaction with the educator fosters a higher sense of safety and comfort for students. The finding also indicates that technology should not be viewed as a replacement for teacher support. Instead, digital media function more effectively when accompanied by direct guidance and scaffolding from educators, particularly for learners with intellectual disabilities who require structured assistance during learning activities (Montoya-Rodríguez et al., 2022). Nevertheless, the use of IT-based flashcard media remains effective provided it is supported by a supportive classroom environment. These empirical findings reinforce the argument by Kirk et al. (2015) that the academic success of students with learning disabilities can be optimized through the implementation of adaptive approaches and appropriate environmental modifications.

Analysis of Usability and User Response (Integration of Interview Data)

Based on the results of implementation observations conducted by two peer observers, this IT-based flashcard medium received a final usability score of 94% (Very Good category). Indicators of student response, classroom interaction, and fulfillment of inclusivity aspects achieved a perfect score (100%). This figure confirms that the use of physical cards can foster an inclusive and conducive classroom atmosphere through enjoyable exploratory activities (Sahrudin, 2023; Sarhindi et al., 2025). This finding is consistent with Layachi and Pitchford (2025), who emphasized that educational technology can promote equitable access and inclusive education when designed to accommodate diverse learner needs and provide engaging learning experiences. The card format facilitates peer-tutor interaction, where typical students act as card readers and students with intellectual disabilities actively scan QR codes to watch videos together. The dynamics of sensory response differences between typical students and students with intellectual disabilities toward media components are presented comparatively in Figure 3.

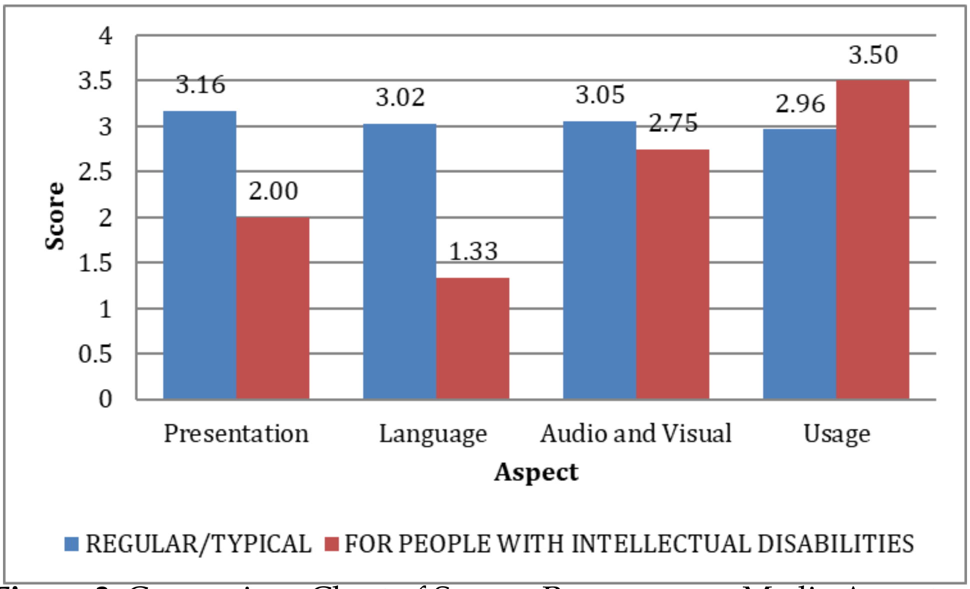


Figure 3. Comparison Chart of Survey Responses on Media Aspects

Figure 3 reveals very distinct differences in learning characteristics. The group of regular students gave the highest rating for the visual presentation aspect (3.16) and the lowest score for the independent use aspect (2.96) because they still require initial operational guidance from the teacher in class. Conversely, Subject I (intellectually disabled) gave the highest absolute score for the ease of motor-tactile use aspect (3.50) as well as the comfort of the audio-visual video animation components (2.75), but gave the lowest score for the written text language aspect (1.33), particularly regarding the indicators of vocabulary comprehension and ease of understanding sentences.

These quantitative survey data align with the results of clinical interviews conducted in the field. Subject I reported being very pleased with the developed media but experienced difficulty when having to read lengthy instructional sentences independently. This finding is also supported by studies indicating that students with intellectual disabilities often experience limitations in working memory and difficulties processing lengthy verbal information, while visual cues and concrete representations are generally more accessible and easier to retain than text-based instructions (Hilal et al., 2026). These empirical findings provide valid evidence confirming the theories of Westwood (2018) and Elya (2024) that children with intellectual disabilities possess very strong visual and tactile learning styles (tangible-visual learners). Similar observations were reported by Layachi and Pitchford (2025), who found that educational technologies incorporating visual supports, interactive content, auditory feedback, and multimodal representations can enhance accessibility and engagement for learners with special educational needs and disabilities. Recent evidence further suggests that multisensory learning environments can support attention, working-memory processes, and cognitive flexibility, thereby facilitating more effective knowledge acquisition compared with single-modality instruction (Gkintoni et al., 2025). Children with intellectual disabilities generally find it easier to grasp information through colors, images, and multimedia motion compared to abstract verbal text. Similar findings have been reported in special education technology research, where interactive digital environments were found to enhance motivation, engagement, self-confidence, and social interaction while supporting the acquisition of knowledge and skills among learners with special educational needs (Kapetanaki et al., 2022).

Interview results with the supervising Physics teacher also confirm the practical value of this medium in the context of general education schools. Amid the limitations of Indonesia's inclusive education system, such as the scarcity of Special Education Teachers (SETs) and schools' administrative unpreparedness to accommodate students with special needs (Sahrudin, 2023), this hybrid medium serves as a self-reliant assistive tool. This finding supports the view that educational technology can function as both an instructional support and an assistive technology that increases accessibility and participation for learners with diverse educational needs in inclusive settings (Kaczorowski et al., 2022). The integration of QR codes provides a multisensory learning experience that simultaneously engages the senses of sight, hearing, and movement, thereby sustaining Subject I's attention span significantly longer in the classroom (Rusdi, 2019; Hallahan & Kauffman, 2021). This finding reinforces the role of educational technology as a complementary instructional tool rather than a substitute for teacher intervention. In inclusive classrooms, teacher scaffolding remains essential to mediate learning, provide immediate feedback, and support students with intellectual disabilities in maintaining engagement and task completion.

This finding is consistent with multisensory learning research suggesting that learning performance improves when visual and auditory information are presented in a congruent manner and learners are able to focus their attention on relevant instructional stimuli (Li & Deng, 2023). This result also supports the multisensory learning perspective, which emphasizes the simultaneous engagement of visual, auditory, kinesthetic, and tactile modalities to strengthen learning experiences and improve understanding of complex concepts (Sanfilippo et al., 2022). The positive response toward the visual and motor-tactile components is in line with evidence suggesting that visual supports can improve on-task behavior, independence, and engagement among learners with intellectual disabilities by presenting information in a more concrete and structured format (Spriggs et al., 2017).

Nevertheless, behavioral observation data indicate that Subject I was less actively engaged in independent group discussions and still required external guidance (prompting) in the form of direct verbal explanations from the teacher. This finding is consistent with previous studies showing that students with intellectual disabilities often demonstrate prompt dependency, relying heavily on teachers or caregivers to complete tasks and transition between learning activities independently (Spriggs et al., 2017). Visual supports can reduce such dependency by providing structured cues that guide students through learning tasks. Similarly, visual scaffolding strategies have been reported to reduce cognitive load, support sequential thinking processes, and gradually facilitate the transition from full assistance toward greater independence among students with intellectual disabilities (Hilal et al., 2026). Therefore, although the IT-based flashcard media successfully supported Subject I's participation and understanding, teacher guidance remained an essential component in maintaining engagement and ensuring successful task completion.

CONCLUSION

Fundamental Findings: IT-based hybrid flashcard media improved learning outcomes for regular students, indicated by an average N-Gain score of 0.55 (moderate category). For the student with intellectual disabilities, the media supported participation and task completion, although conceptual understanding still required teacher assistance. **Implications:** These findings support Cognitive Theory of Multimedia Learning and Cognitive Load Theory, showing that multimodal instructional media can help reduce cognitive load in learning abstract concepts. Practically, the media is useful for inclusive classrooms when accompanied by teacher scaffolding. **Limitations:** This study is limited by a small sample size, a single classroom setting, and the inclusion of only one student with intellectual disabilities. In addition, the study focuses on short-term learning outcomes without assessing long-term retention. **Future Research:** Future studies should involve larger samples across multiple inclusive schools and use more rigorous experimental or single-subject designs (e.g., A-B-A-B). Further research is also needed to examine long-term retention and explore adaptive or AI-based enhancements for inclusive learning media.

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