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Development of a Javanese Script Learning Website Based on Experiential Learning and Audio Instructional to Enhance Javanese Script Grapheme Literacy of Visually Impaired Children

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ABSTRACT

The fostering of Javanese script literacy should be implemented across all levels of Javanese society, including visually impaired children, as part of an inclusive effort to preserve cultural heritage. However, the limited availability of accessible learning media remains a major challenge in Javanese script instruction. Therefore, this study aims to develop an audio-instruction-based learning website for visually impaired students, integrated with the experiential learning model and packaged as a game-based challenge called Bagong's Smart, to introduce and train students in writing complete and accurate Javanese script graphemes. This study employed the Four-D (4D) development model, consisting of the define, design, develop, and disseminate stages. Website development was carried out using PHP and the Laravel framework in Visual Studio Code. The Javanese script font used was Mbata Sarimbag, which has been shown to help visually impaired students more easily recognize and map grapheme patterns in Javanese script. The research was conducted at SLB Negeri Semarang using observation, interviews, and questionnaires as data collection techniques. Data analysis was carried out through media feasibility testing, Javanese script material feasibility testing, and evaluation of the media's potential to support learning. The results indicate that Bagong's Smart is highly feasible for use in learning the Javanese script by students with disabilities. This feasibility is supported by the media validation results, which achieved an average score of 91.1%, and the material validation results, which reached an average score of 97.3%. In addition, the Bagong's Smart website demonstrated the potential to support visually impaired students' ability to write complete and accurate Javanese script graphemes, as evidenced by the average score for students' independent Javanese script writing, which reached 81.9%. This study offers an alternative website-based digital learning platform that optimizes audio instructional features and direct learning experiences to expand educational accessibility for visually impaired students.

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■ INTRODUCTION

The promotion of Javanese script literacy should be implemented across all levels of Javanese society, including children with visual impairments. However, in practice, the Javanese community, particularly students, faces several challenges in learning the Javanese script. Javanese script instruction is still perceived as difficult and monotonous by students, due to the use of overly conventional teaching models and learning media that rely solely on textbooks and Javanese script charts (Cahyani & Subrata, 2022). Furthermore, based on preliminary research at SDN Sentul 02 Pati, 90% of students reported that Javanese script instruction relied exclusively on textbooks or student worksheets, resulting in 80% of students having difficulty understanding the material. In addition, it was found that 64.1% of 2,437 students across 14 senior high schools (SMA/MA) in Central Java, Indonesia, had difficulty properly memorizing Javanese script, particularly the forms of *aksara nglegena*, *aksara murda*, and *aksara rekan*. The large number of students who struggle to memorize Javanese script forms has hindered the literacy process among students. Therefore, if Javanese script learning is already considered difficult

for sighted children, it is even more challenging for children with disabilities, especially those with visual impairments. In fact, Law Number 8 of 2016 concerning Persons with Disabilities explicitly affirms that every child with special needs has the right to equitable and inclusive education.

Based on the findings of Tisnawati et al. (2022), the limited availability of learning media, textbooks, and instructional materials frequently leads teachers in visually impaired classrooms to omit instruction on the introduction and writing of Javanese script. This finding is supported by interviews conducted with several teachers and students in visually impaired classes at SLB Negeri Semarang. The lack of compatible and easily accessible Javanese script learning media has hindered the implementation of Javanese script instruction for visually impaired students at the school. However, digital learning media can also facilitate students' conceptual understanding of the learning materials (Kasiyun et al., 2026). Students with visual impairments are generally familiar with Javanese script only in Braille, without understanding its original visual forms or proper writing conventions. Moreover, teachers in visually impaired classes at SLB Negeri Semarang often lack sufficient competence in teaching the Javanese script, leading to recurring challenges with instructional methods and learning media. In fact, Central Java Governor Regulation Number 57 of 2013 concerning the implementation guidelines of Regional Regulation of Central Java Province Number 9 of 2012 on Javanese language, literature, and script, Article 5 paragraph (1), stipulates that the development of Javanese language, literature, and script must also be carried out in SDLB, SMPLB, and SMALB. Therefore, appropriate instructional models and learning media are urgently needed to facilitate the effective learning of the Javanese script by visually impaired students.

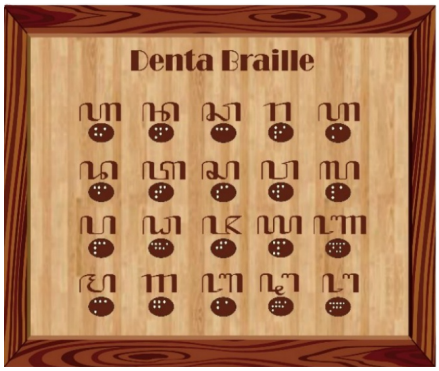

Figure 1. Javanese script braille

The registration of the Javanese script in Unicode in 2009 has enabled its application in digital devices. This development has provided broader access for Javanese communities to use the script in daily life. The digitalization of the Javanese script has opened wider literacy opportunities that are more accessible and easier to disseminate to the public, especially children. The flexible and expansive nature of the digital environment offers students the opportunity to learn independently anytime and anywhere with improved learning quality (Kerimbayev et al., 2023). Such digital learning media have the potential to foster more widespread and inclusive literacy in the Javanese script among Javanese communities, as they can be easily accessed on personal digital devices. Furthermore, the use of digital platforms positively impacts cultural preservation, as platforms with broad, rapid, and convenient access provide opportunities for people worldwide to engage with cultural content (Jin & Liu, 2022; Zhou et al., 2026). Therefore, the digitalization of the Javanese script may also help persons with disabilities, particularly those with visual impairments, learn the script more effectively. Script learning integrated with the screen reader feature commonly used by individuals with visual impairments, namely NVDA (NonVisual Desktop Access), has proven effective in helping students with visual impairments understand the script learning materials. (Amin et al., 2025; Kapperman et al., 2021).

By learning to write the Javanese script, children with visual impairments can recognize and write Javanese characters correctly, thereby fostering a strong sense of belonging to Javanese culture as an essential component of Javanese cultural identity. Learning local scripts enables children to better understand the culture that is owned and inherited within their own community (Akkapram, 2020; Nakata, 2024). Moreover, the Javanese script writing skills acquired by children with visual impairments hold significant potential when applied to practical skills such as weaving, carving, and producing other handicrafts. The outcomes of these Javanese script–based creative skills among visually impaired children have the potential to enter Indonesia's creative industry sector. This is in line with the findings of Putra and Muttaqien (2024), who explain that using the Javanese script in the creative industry is an effective product marketing strategy. Therefore, when children with visual impairments develop proficiency in writing Javanese script, they are expected to integrate this proficiency into their existing practical and creative skills.

Creative and innovative learning models are highly needed to optimize the learning process, thereby supporting students' understanding and creating a more engaging and enjoyable learning environment (Rahimi & Shute, 2021; Tu et al., 2023). This is particularly important in Javanese script instruction for students with visual impairments, as it helps establish an appropriate and enjoyable learning environment. One such approach is the experiential learning model, which actively engages students through direct experience (Henríquez et al., 2025). In the context of educating students with visual impairments, learning to write the Javanese script in its authentic forms can be categorized as experiential learning, as it provides concrete experiences for visually impaired students in writing the script in its original form. The implementation of experiential learning in educational settings encourages students to develop understanding and skills through authentic experiences (Bertoni & Bertoni, 2020). Moreover, experiential learning can enhance students' enthusiasm and learning motivation, as it enables them to experience success in understanding problems and applying their knowledge to solve them (Kong, 2021).

In addition, challenge-based learning, or the game-based challenge learning model, can have a significant positive impact on children's cognitive, social, and emotional outcomes, as well as on their motivation to learn (Alotaibi, 2024). Learning becomes more enjoyable, engaging, and sustainable when instructional activities incorporate game-based mechanisms such as points, symbols, and leaderboards (Şenocak et al., 2021). Through the implementation of the game-based challenge model, students become more motivated and actively engaged in the learning process, and are encouraged to think creatively and innovatively when formulating solutions to various learning challenges (Gallagher & Savage, 2023). Therefore, integrating the experiential learning model with a game-based challenge approach into an interactive learning medium is expected to enhance interest and literacy skills in Javanese script among children with visual impairments.

According to Prestama et al. (2022), the use of Javanese script learning media has been shown to be effective in improving students' Javanese script writing skills. It is also acknowledged that website-based e-learning media, which offer flexible access without time or place limitations, are highly effective in enhancing students' motivation to learn and facilitating the learning process (Camilleri & Camilleri, 2023; Ratnaningsih et al., 2020). The incorporation of features such as screen readers, keyboard navigation, Assistive Technologies (ATs), and high-contrast settings on a website is essential to ensure equal access for users with visual impairments to the same level as general users (Cipresso et al., 2018; Kerdar et al., 2024; Rakhmawati & Dewanto, 2025). Furthermore, Ferreira & Ribeiro (2023) describe the development of a Visual Studio Code plugin to improve website accessibility for visually impaired users. Their study demonstrated a reduction in critical accessibility errors and an increase in user comfort for individuals with visual impairments.

Based on the aforementioned discussion, Bagong's Smart (Bridging *Aksara Jawa* for Outstanding New Generation), a learning website grounded in experiential learning and integrated with audio instructional features, represents an essential innovation for fostering literacy in the Javanese script in the present context. The flexibility in time, location, and device accessibility enables users (particularly children with visual impairments) to access learning materials on the website anytime, anywhere, to enhance their Javanese script literacy skills.

The development of the Bagong's Smart website represents a further innovation derived from the Denta Braille learning media developed by the authors, which was designed to meet the needs of children with visual impairments in learning the Javanese script. In addition, the Bagong's Smart website is also an advancement of the Aksawatra learning media introduced at SLB Negeri Semarang by Nagara et al. (2024). The Aksawatra learning media is a touchpad-based technological learning tool that enables teachers or visually impaired students to recognize the original visual forms of the Javanese script. However, access to the Aksawatra learning media is limited to the school environment. Therefore, the development of Bagong's Smart website

Figure 2. Aksawatra Javanese script learning media

addresses the limitations of Aksawatra media. Equipped with accessibility features for visually impaired users, flexible access that allows use at any time and anywhere, and interactive, engaging learning models, the Bagong's Smart website is expected to help improve Javanese script literacy among students with visual impairments.

Based on the aforementioned background, the research questions of this study are as follows: (1) what are the needs for developing the Bagong's Smart website for visually impaired students in learning to write Javanese script graphemes; (2) how can the prototype of the Bagong's Smart website be designed in accordance with the learning needs of visually impaired students in Javanese script instruction; and (3) how the initia; implementation of the Bagong's Smart website demonstrates the potential to facilitate comprehensive learning of javanese script grapheme writing for visually impaired students.

■ METHOD

Participants

The study population comprised 23 students with visual impairments at SLB Negeri Semarang. The sampling technique employed was purposive sampling, in which samples were selected based on specific criteria or objectives determined by the researcher (Sugiyono, 2021). The sampling criteria included visually impaired students who possessed the skills to operate a laptop or computer and the ability to access websites. This sampling criterion serves to minimize external bias and to ensure that the results can be more appropriately interpreted as an indication of the website's pedagogical intervention's contribution to Javanese script-writing ability, rather than as an effect of variations in students' technological proficiency. Based on these criteria, six students with visual impairments were selected as research participants. The relatively small sample size was attributed to the limited availability of research participants who could access and operate the website. Furthermore, this study aimed to examine the website's acceptability to visually impaired students for learning to write Javanese script. Therefore, the inclusion of six participants who met the established sampling criteria was considered sufficiently relevant to the study's objectives. The variables in this study comprised the Bagong's Smart website as the independent variable and Javanese script learning outcomes as the dependent variable.

Research Design and Procedures

This study employs a research and development (R&D) approach. The research design applied in this study is the Four-D (4D) model. This model consists of four main stages: Define, Design, Development, and Disseminate (Khaeroni, 2021). The research procedures are presented in Figure 3. The website evaluation was conducted using a One-Shot Case Study design to identify indications of support for visually impaired students' ability to write Javanese script on Bagong's Smart website. The evaluation was based on post-test results obtained after students practiced writing Javanese script with audio guidance through the website. The percentage results were determined by assessing the similarity and accuracy of the Javanese script independently written by visually impaired students after completing the writing exercises on the website. The assessment was conducted by analyzing three Javanese script texts produced by the students following the instructional session. The assessment was conducted via a touchscreen on a blank canvas on the website, without instructional audio. The test was conducted by writing Javanese script on a blank canvas using a touchscreen on the website,

Figure 3. Website development procedures

without instructional audio, so that students relied on their prior writing practice and their knowledge of Javanese script patterns from previous training sessions. This approach is consistent with the study conducted by Aslan (2025), which emphasizes that the assessment of writing skills among visually impaired students does not depend on the quantity of written output, but rather on the presence and characteristics of errors in their writing. Therefore, a small yet representative sample of written texts is considered sufficient to describe the writing abilities of visually impaired students and to identify patterns of errors.

Instruments

The data in this study were collected through observations, interviews, questionnaires, and students' test results. Observations were conducted by examining the process of visually impaired students accessing the Bagong's Smart website, from homepage navigation to the Javanese script writing exercises provided on the website, including Javanese script writing tests completed without audio instructions. Interviews and questionnaires were administered to teachers and visually impaired students using guided questions focusing on the need for Javanese script learning media for visually impaired learners, the accessibility features required for visually impaired users, and learning models that can enhance students' engagement in learning Javanese script. Questionnaires were also distributed to media experts and Javanese script material experts to obtain validation regarding the feasibility of both the learning media and the Javanese script materials presented on the Bagong's Smart website. The test was conducted by asking visually impaired students to write one of the Javanese script characters they had learned three times without audio cues, thereby documenting the students' Javanese script writing outcomes.

Data Analysis

The qualitative data analysis in this study employed the interactive analysis model proposed by Miles, Huberman, and Saldana (2019), which consists of three main stages: data reduction, data display, and conclusion drawing and verification. The data reduction process was carried out by identifying observation, interview, and questionnaire data relevant to the development of the Bagong's Smart website and the implementation of Javanese script learning through the website. Data were presented as narrative descriptions to illustrate the process of website accessibility for visually impaired students, pattern-based Javanese script writing exercises on the website, and the development of students' Javanese script grapheme writing skills and learning interest after practicing with the Bagong's Smart website. The qualitative analysis focused on the accessibility process of the Bagong's Smart website and the responses of visually impaired students toward learning Javanese script writing through the website.

The quantitative data analysis in this study included the feasibility test results and an evaluation of the initial potential of Bagong's Smart website to support learning. The feasibility analysis was conducted through questionnaire assessments administered to two validators, namely a Javanese script expert and an inclusive education expert, to evaluate the quality of Bagong's Smart website in terms of accessibility feasibility, learning model suitability, and the appropriateness of Javanese script materials for visually impaired students. The feasibility percentage was calculated by comparing the total score from the experts' evaluations with the maximum ideal score, then multiplying the result by 100%. Accordingly, the resulting percentage reflected the website's overall feasibility based on the validators' comprehensive evaluations. Furthermore, the feasibility test results for Bagong's Smart website were interpreted using the criteria presented in Table 1. The website developed in this study is considered to receive a positive response and be suitable for use if the feasibility test results indicate a percentage score exceeding 75% (Creswell & Creswell, 2022).

Table 1. Feasibility test criteria for the Bagong's smart website (Creswell & Creswell, 2022)

Score Percentage	Category
$1\% \leq P \leq 40\%$	Unsatisfactory
$50\% < P \leq 75\%$	Satisfactory
$75\% < P \leq 80\%$	Good
$80\% < P \leq 100\%$	Very Good

The three Javanese script writing samples produced by each student were subsequently assessed, and the average level of mastery was calculated. The percentage of consistency in Javanese script writing was calculated by comparing the total score of the writing assessment to the maximum possible score, then multiplying the result by 100%. This percentage reflected the level of consistency in the formation of Javanese script writing produced by visually impaired students.

Table 2. Assessment criteria for Javanese script writing test results (Sundayana, 2018)

Score Total	Score Precentage	Form Category	Category
0-4	≥50%	Not Yet Formed	The grapheme structure does not yet resemble the target character
5-6	51%≤P≤75%	Partially Formed	The structure has begun to emerge, but it is not yet stable or remains ambiguous
7-8	76%≤P≤100%	Well Formed	The structure is fully formed and completely conforms to the target character.

Furthermore, the results of the feasibility test for Bagong's Smart website were interpreted using the criteria presented in Table 2. The media was considered to demonstrate positive indications in supporting and improving Javanese script literacy among visually impaired students if at least 75% of the students achieved the mastery criterion (Sundayana, 2018). Therefore, in this study, mastery was determined by the average score for the formation accuracy of each visually impaired student's Javanese script writing outcomes.

The measurement of graphemes in the handwritten outputs of students with visual impairments in this study adopts the handwriting assessment framework developed by Sparaci et al., (2025), which refers to 13 grapho-motor parameters (GMPs): (1) handwriting size, (2) margin alignment, (3) sentence alignment, (4) word spacing, (5) acute/long joins, (6) interrupted/overlapping joins, (7) letter collisions, (8) irregular letter size, (9) incoherent letter size, (10) letter distortions, (11) ambiguous letters, (12) self-corrections, and (13) unsteady trace. The GMP-based assessment was employed because handwriting is understood as a graphomotor activity involving fine motor control and spatial perception, thereby requiring an objective, measurable, and sensitive evaluation of variations in children's writing (Downing & Caravolas, 2023). Nevertheless, in this study, adjustments and simplifications were made to the GMPs-based assessment components to evaluate Javanese script writing produced independently by visually impaired students, without guidance from the website's audio instructional features. These modifications were implemented to ensure alignment with the study's objectives and the characteristics of the abilities of visually impaired students (see Table 3 for the assessment description).

Table 3. Assessment criteria for Javanese script writing of children with visual impairments

No	Aspect	Scoring
1	**Basic Forms of Javanese Script (Core Graphemes)**	The basic letter form aspect assesses the degree of conformity between the written Javanese grapheme and its ideal form, including the clarity of primary elements, curves, and structural strokes that compose the character. A score of 2 is assigned when the character is clearly formed, complete, and easily recognizable without distortion. A score of 1 is assigned when minor distortions are present in parts of the character, yet the identity of the grapheme remains recognizable. A score of 0 is assigned when the character exhibits significant distortion or ambiguity, making it difficult to recognize or causing it to resemble another character.
2	**Stroke Direction and Sequence**	The stroke direction and sequence aspect evaluates the stability, continuity, and fluency of hand movements in forming the characters. A score of 2 is assigned when the strokes are stable, continuous, and demonstrate a consistent writing flow. A score of 1 is assigned when the strokes are relatively stable but show minor irregularities, such as repeated strokes or slight changes in direction. A score of 0 is assigned when the strokes are unstable, frequently interrupted, overlapping, or indicate uncertainty in direction and writing sequence.

3	**Letter Structure**	The character structure aspect assesses the coherence and relationship among the components of a Javanese grapheme within a single character. A score of 2 is assigned when the character structure is complete, each component is proportionally arranged, and all parts are well connected. A score of 1 is assigned when the structure is less orderly or slightly disproportionate, yet the relationships among the components remain identifiable. A score of 0 is assigned when the character structure is incomplete, with components overlapping or separated in ways that make the relationships among them unclear.
4	**Letter Proportions**	The character proportion aspect evaluates the appropriateness of character size, consistency of size across characters, and the regularity of spacing between graphemes or words. A score of 2 is assigned when the character size is consistent, proportional, and the spacing between characters or words is well organized. A score of 1 is assigned when variations in size or spacing occur but do not significantly interfere with readability. A score of 0 is assigned when character size and spacing are highly inconsistent, thereby disrupting the orderliness and readability of the writing.

■ RESULT AND DISCUSSION

This study develops an audio-based instructional learning website integrated with experiential learning, presented as a game-based challenge for children with visual impairments, entitled Bagong's Smart (Bridging *Aksara Jawa* with Game for Outstanding New Generation). The Bagong's Smart website is a web-based learning platform that supports Javanese script-writing instruction for students with visual impairments through an experiential learning model with audio support. The development of the Bagong's Smart website aims to introduce and develop Javanese script-writing skills among children with visual impairments through the Four-D (4D) stages of development. The following section provides a more detailed explanation of the development process for Bagong's Smart website.

Define

The define stage aims to identify needs and analyze the existing learning conditions. This stage consists of four main steps: preliminary analysis, learner analysis, concept analysis, and the specification of learning objectives (Khaeroni, 2021). The outcomes of these four steps form the foundation for developing Bagong's Smart website as a learning medium for teaching Javanese script writing to students with visual impairments. Based on interviews conducted with teachers and students at SLB Negeri Semarang on July 15, 2025, it was found that Javanese script instruction in visually impaired classrooms has not yet been implemented optimally and remains limited to the use of Javanese script in Braille form. In addition, teachers of visually impaired classes at SLB Negeri Semarang reported difficulties teaching Javanese script due to limited instructional media and insufficient competence in Javanese script literacy. Previously, students with visual impairments received instruction in the original forms of the Javanese script through an Arduino-based wooden Javanese script board called Aksawatra. However, the Javanese script has not been used for a considerable time in Javanese script instruction in visually impaired classrooms at SLB Negeri Semarang. This is because several visually impaired students still experienced difficulty in imagining the original forms of the Javanese script through Aksawatra. In addition, the relatively high production cost and limited availability of the media have constrained its accessibility in terms of the time and place of use.

Based on interviews conducted with teachers of students with visual impairments, it was stated that Javanese language instruction, particularly Javanese script learning, has not yet implemented digital learning media. This differs from other subjects, which have begun to use digital learning media through smartphones or computers in the learning process. Teachers of visually impaired classes at SLB Negeri Semarang also expressed the opinion that digital learning media, especially websites designed to be accessible to students with visual impairments, have great potential to support Javanese script instruction. In addition, several students and teachers with visual impairments stated that students feel more comfortable learning when they are allowed to study independently. Some students expressed that having the freedom to learn provides greater enjoyment and self-confidence for students with visual impairments than learning

Table 4. Accessible learning website features and interface criteria for students with visual impairments

No	Features and Interface of a Disability-Friendly Website
1	Clear, sequential, and comprehensible audio instructions
2	All features on the website must be equipped with audio
3	All materials and navigation on the website must be readable by a screen reader
4	The website layout should be horizontal
5	Symbols that cannot be read by a screen reader should be avoided
6	A simple login system that does not require complicated steps, using only an email address or a combination of username and password.
7	Avoid the use of CAPTCHA
8	Clear and non-confusing navigation
9	Provide clear audio narration and descriptions
10	Include audio guidance when navigating between pages
11	Provide feedback features when learning to write Javanese script
12	Background music is not necessary

under direct teacher supervision.

Based on the results of the questionnaire distribution and needs assessment interviews related to the development of a Javanese script website, several criteria for visual-impairment accessibility features and website display were identified, as recommended by teachers and students with visual impairments at SLB Negeri Semarang. The website criteria that need to be considered and implemented to facilitate accessibility for students with visual impairments are presented in Table 4.

Teachers and students with visual impairments have been able to operate smartphones, laptops, and computers by optimizing the audio output of screen readers. NVDA (Non-Visual Desktop Access) is a screen reader commonly used by individuals with visual impairments when operating laptops. Therefore, it can be understood that with the use of NVDA, students with visual impairments will not experience difficulties in accessing digital-based Javanese script learning media, particularly websites. The learning objectives were developed by referencing the learning outcomes of the Merdeka Curriculum. The learning outcomes and learning objectives are presented in Table 5.

Design

At this stage, the researcher designed the User Interface (UI) for Bagong's Smart website using CorelDRAW. The interface design process began with the creation of an account login button, a sign-in button, and a guest button that allows users to access the website without requiring an account. Subsequently, the overall website design was developed, including the screen reader selection feature, the chapter division within the Bagong's Smart website, the game mode, and the scripting of Javanese script patterns used in the system (see Table 6). The Bagonog's Smart game is structured into chapters, with Chapter 1 consisting of 30 levels. This initial chapter comprises 20 Javanese nglegena characters, 9 sandhangan, and 1 additional level. Within this framework, each level provides a dedicated writing exercise focused on a single Javanese character or sandhangan.

The Javanese script font used in the game is based on the Mbata Sarimbag model. This Javanese font features a writing style that tends to be cubistic in form, as illustrated in Figure 4. The use of this font is intended to help developers provide clear instructions for writing Javanese script. Implementing the

Table 5. Learning outcomes and objectives

Learning Outcome	Learning Objectives
Students can write the 20 basic Javanese characters (*legena*), *pasangan*, *sandhangan swara*, and *sandhangan panyigeg wanda*.	1. Through the implementation of the experiential learning model, students with visual impairments are able to write the Javanese script (*legena*) in accordance with its original form. 2. Through the implementation of the experiential learning model, students with visual impairments are able to write Javanese script using appropriate procedures and correct sequencing.

Table 5. Javanese Script Patterns in the Bagong's Smart Website

Javanese Script	Latin	Grapheme Pattern
ꦲ	*ha*	↑ → ↓ → ↑ → ↓ ↑ → ↓
ꦤ	*na*	↑ → ↓ ↑ → ↓ ← ↑ → ↓
ꦕ	*ca*	↑ → ↓ ← ↑ ↘ ↑ ← ↗ ↓
ꦫ	*ra*	→ ↓ ↑ → ↓
ꦏ	*ka*	↑ → ↓ ↑ → ↓ ← ↑ → ↓ ↑ → ↓
ꦢ	*da*	↑ → ↓ ↗ ↓ ← ↑ → ↓
ꦠ	*ta*	↑ → ↓ → ↑ ← ↑ → ↓ ↑ → ↓
ꦱ	*sa*	↑ → ↓ ← ↑ ↘ ↑ → ↓
ꦮ	*wa*	↑ → ↓ → ↑ ← ↗ ↓
ꦭ	*la*	↑ → ↓ ↑ → ↓ → ↑ → ↓
ꦥ	*pa*	↑ → ↓ → ↑ → ↓
ꦝ	*dha*	↑ → ↓ ↗ ↘ ↑ ← ↗ ↓
ꦗ	*ja*	↑ → ↓ → ↑ → ↙ ↘
ꦪ	*ya*	↑ → ↓ → ↑ → ↓ → ↑ → ↓
ꦚ	*nya*	↑ → ↓ ↗ ° ↑ → ↓ ↑ → ↓ ↑ → ↓ ↑ → ↓
ꦩ	*ma*	↑ → ↙ → ↙ → ↑ → ↓
ꦒ	*ga*	→ ↓ ↑ → ↓ ↑ → ↓
ꦧ	*ba*	↑ → ↓ ↗ ° ↑ → ↓ ↑ → ↓ ↑ → ↓
ꦛ	*tha*	↑ → ↓ → ↑ ← ↓ → ° ↑ → ↓ ↑ → ↓
ꦔ	*nga*	↑ → ↓ ↗ ° ↑ → ↓ ↑ → ↓
◌ꦶ	*i*	→ ↓ ← ↑
◌ꦸ	*u*	↓ → ↑
ꦼ◌	*e*	↑ → ↓ ↑ → ↓↓
ꦼ◌◌ꦺ	*o*	↑ → ↓ ↑ → ↓↓ ° ↗ → ↙ →
◌ꦾ	*ê*	← ↑ → ↓ ←
◌ꦽ	*r*	↗
◌ꦿ	*h*	→ ↓ ↘
◌ꦁ	*ng*	↑ ← ↓ → ↗
◌ꦃ	/	→ → ↑ → ↓

Mbata Sarimbag model simplifies and clarifies writing instructions for students with visual impairments. The application of the *Mbata Sarimbag* writing model is grounded in the study conducted by Schmalz et al. (2022), which explains that the more complex the letter forms and grapheme–phoneme correspondence rules, the more difficult they are for students to learn. Conversely, simple, consistent orthographic systems are more easily internalized, as they minimize confusion when establishing fundamental reading and writing rules. Therefore, the use of the Mbata Sarimbag writing model represents an appropriate approach for Javanese script writing exercises for students with visual impairments in the Bagong's Smart game.

Development

The development stage was conducted in two iterative cycles. The first cycle resulted in a functional prototype consisting of chapters that included 20 levels of Javanese nglegena script exercises and 9 levels of Javanese sandhangan script exercises. Prior to starting the game, three modes are provided on the website: (1) the first mode, namely the "Materi" mode, contains a collection of Javanese script patterns presented through audio instructions that can be studied by students with visual impairments before beginning the game; (2) the second mode is the writing mode, which consists of a Javanese script writing game; and (3) the final mode is the free mode, which functions as a space for students with visual impairments to write Javanese script independently without any guidance.

From the outset, the design prioritized fundamental accessibility through keyboard navigation, a roving tabindex mechanism, and a

Figure 4. Mbata Sarimbag Javanese script writing model

manually audio-based screen reader. The progress system was designed to be flexible, allowing it to be used in either login or guest mode. In letter-writing activities, the writing instructions followed the Mbata Sarimbag model, which tends to be cubistic in form, enabling the audio instructions to be mapped into a structured stop–go sequence at specific checkpoints.

The game design in Unity focused on accessibility, instructional flow, and data integration. A stop–go checkpoint system was implemented to map the steps of writing Javanese grapheme characters into structured segments. Keyboard-first navigation and a roving tabindex mechanism were aligned with a focus overlay on the canvas, while audio narration was separated into focus cues, confirmation messages, and error feedback. The web–game integration used Unity WebGL via an iframe with query parameters (id, chapter, soal_id) to load specific levels.

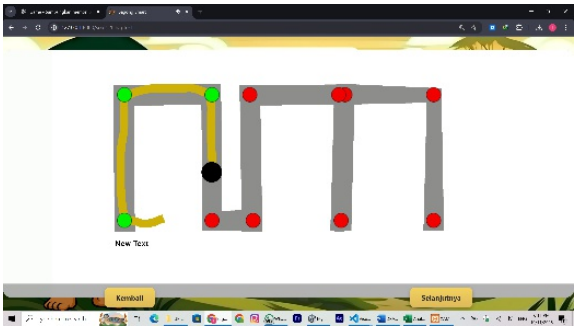

Figure 5. Simulation of writing the Javanese character "Ha" on the Bagong's smart website

Meanwhile, the progress reporter transmitted attempt results and level status to the back-end system (login mode stored user achievements, whereas guest mode was intended for quick trials). From a performance perspective, assets were packaged per chapter, essential audio files were preloaded, a responsive 16:9 aspect ratio was maintained, and loading indicators were provided to reduce initial cognitive load.

The Javanese grapheme writing patterns, presented as audio instructions, were also integrated into the material menu, which contains a collection of Javanese graphemes. This integration was intended to maintain alignment between the audio instructions provided in the learning materials and those used in the game, as well as to facilitate students with visual impairments in understanding and memorizing Javanese grapheme patterns. The prototype was subsequently validated by subject-matter experts and media experts prior to being piloted

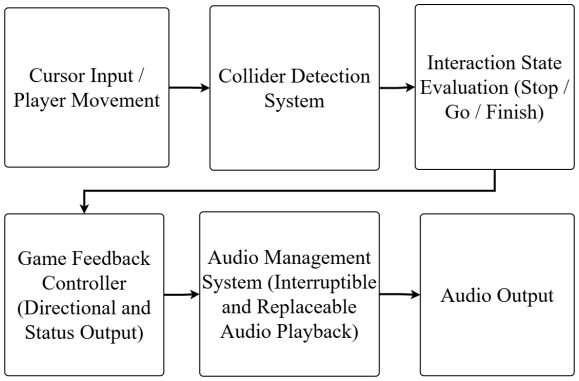

Figure 6. System architecture flowchart of collision-based interaction with asynchronous audio feedback mechanism

on a limited basis with students with visual impairments and their accompanying teachers.

The material validity aspects of this website were adapted from the study conducted by Setiaji et al. (2022), which encompasses four components: content feasibility, presentation feasibility, linguistic feasibility, and contextual assessment. The results of the material validity evaluation of the Bagong's Smart website indicate a "very good" category, with an average score of 97.3%. The content feasibility and contextual assessment aspects each achieved 100%, while the presentation aspect reached 92.8% and the linguistic aspect 96.4%. The primary feedback from experts emphasized the need for precise instructional guidance to ensure the technology is truly appropriate and functional for users with visual impairments. These findings confirm that the content, scope of material, and language components are robust; therefore, subsequent improvements focused on enhancing user experience and instructional flow. the recapitulation of the content validity for the Bagong's Smart website across four main aspects. Overall, the evaluation indicates highly favorable validity scores. Both Content Feasibility (items 1–5) and Contextual Assessment (items 20–21) achieved perfect results, each obtaining an average score of 4.0 out of 4.0, which translates to a perfect validity percentage of 100%. Meanwhile, Presentation Feasibility (items 6–12) received an average score of 3.7 with a validity percentage of 92.8%. Lastly, the Linguistic Feasibility aspect (items 12–19) scored an average of 3.8,

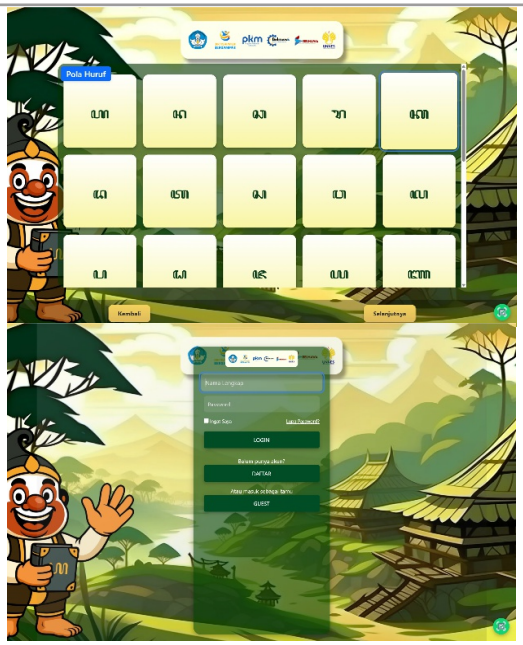

Figure 7. Design of the pattern page for each javanese script grapheme and design of the login page

resulting in a high validity percentage of 96.4%.

The aspects employed in this study were developed from the media feasibility aspects proposed by Pratama et al. (2023). These aspects were further adapted to accommodate the specific needs of students with visual impairments. The media validity results fall within the "good" category, with an average score of 79.1% for visual design, 78.5% for accessibility features, and 75.0% for practicality and independence. Key feedback emphasized the importance of providing students with initial tactile experiences with letter forms, the need for guidance during the orientation phase, compatibility with commonly used screen readers, and the inclusion of an introductory page explaining the game rules and practical benefits. These findings indicate areas for improvement in practical accessibility, control clarity, and user independence from the initial screen. The media validity of the Bagong's Smart website was assessed across three components based on Pratama et al. (2023). The Visual Design aspect (items 1–6) achieved an average score of 3.1 out of 4.0, yielding a validity percentage of 79.1%. Similarly, Accessibility Features (items 7–13) obtained an average score of 3.1, which corresponds to a validity percentage of 78.5%. Lastly, the Practicality and Independence aspect (items 14–20) recorded an average score of 3.0, resulting in a validity percentage of 75.0%.

The experts' primary recommendations focused on improving keyboard controls, loading speed, and the clarity of instructions. Overall, the development findings indicate that the content has reached a stable level of quality. At the same time, further refinements focus on enhancing the user experience to sustain high learning engagement from the initial trial stage.

The Bagong Smart website was further refined to better accommodate students with visual impairments, ensuring greater accessibility. These improvements addressed practical accessibility constraints identified in the first cycle, particularly screen reader latency, overlapping audio output, and the need for clear initial orientation. A key intervention was the addition of an Attention/Welcome screen that audibly offers two options at the outset: using the website's built-in voice or the device's screen reader. This mechanism responds to feedback from students and the Chair of Pertuni (Persatuan Tunanetra Indonesia), who is also a teacher in the visual impairment class at SLB Negeri Semarang, by transferring control over the narration source to the user. At the same time, it resolves issues of overlapping audio and inconsistent reading tempo. From a design perspective, this flow is structured using stop-before-play logic, ensuring that each shift in focus first pauses any ongoing audio before playing new narration. This approach ultimately reduces cognitive load at the initial point of entry into the system.

The second intervention involved adding a pattern-recall page before the start of the game. This page serves as a conceptual bridge, introducing the basic movement patterns for writing letters, namely: step segmentation using the stop–go structure, directional cues, and checkpoint markers, along with brief examples. The inclusion of this page follows the recommendation of media experts to provide an explicit orientation prerequisite for users, without the need to conduct a second round of student trials The optimization of instructional audio on the website is aligned with the findings of Uulu et al. (2021), which state that the use of audio media in learning for students with visual impairments has proven effective in facilitating comprehension and supporting students in visualizing the material explained through audio. Therefore, from an instructional perspective, the pattern recall for each Javanese character can shorten orientation time, standardize the audio terminology used within levels, and reduce the need for assistance during the initial phase. For example, the Javanese character "Ga" is written using the following stroke pattern: → ↓ ↑ → ↓ ↑ → ↓ .

The third refinement targeted media validity components that had previously been rated as "good" but had not yet reached the "very good" category. Therefore, feasible improvements were implemented without imposing additional system burden. These improvements included ensuring a consistent focus hierarchy for keyboard-first navigation, consolidating typography and contrast for selected elements, optimizing loading performance through critical audio preloading and chapter-level asset separation, and adding informative progress indicators. These measures were realistically achievable and directly aligned with the media evaluation criteria (visual design, accessibility, and practicality/independence). Optional and high-cost recommendations were deferred to ensure that the re-validation process concentrated on the most substantive and impactful changes.

With this revision structure, the media re-validation focused on measuring three indicators: (1) accessibility following the implementation of audio source selection and deterministic audio control; (2) practicality and independence after the addition of the pattern recall page and the default keyboard-first navigation; and (3) user interface (UI) and user experience (UX) following focus consolidation and loading optimization. The improvements were expected to elevate the rating from the "good" range to "very good" according to the evaluation rubric, without making additional claims regarding the media's indicated educational benefits, as no further student trials were conducted. Once the re-validation scores were obtained, this section was supplemented with the actual scores for each indicator and a summary of the remaining gaps. Based on the revalidation results, all indicators showed significant improvements after revisions were made. First, the Visual Design score increased from 79.17% to 91.17%. Second, the percentage for Accessibility Features rose from 78.57% to 89.28%. Finally, the Practicality and Independence indicator experienced the highest increase, jumping from 75% to 92.85%.

The results of the trial implementation of the Javanese script-writing website for students with visual impairments, using a one-shot case study design, indicate that 4 out of 6 students were able to write Javanese characters, achieving a similarity score of ≥76% across three attempts at writing a single character. The average mastery percentage for the six students, as reflected in the similarity scores of their Javanese character writing, was 81.9%, indicating the media's potential to support visually impaired students in recognizing and writing Javanese script in its original form. The following section presents a summary of the Javanese script writing results of students with visual impairments after practicing through the Bagong's Smart website, as shown in Figure 8.

Based on these data, it can be concluded that the Bagong's Smart website demonstrates the potential to introduce and train students with visual impairments to write authentic Javanese graphemes in their complete and original forms, even though the students had previously been unable to write Javanese script at all. This finding is supported by a statement from a teacher with visual impairments, who indicated that recognizing a single letter form generally requires at least one week of repeated practice. Therefore, the mastery test results for students with visual impairments provide evidence that Bagong's Smart website has a significant positive impact on their experience writing authentic Javanese script graphemes.

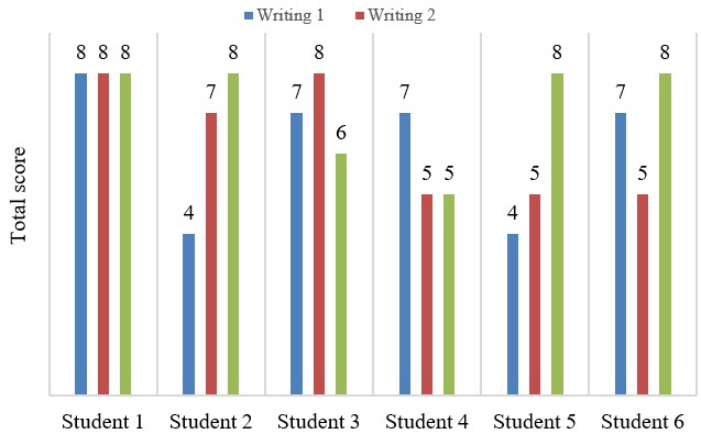

Figure 8. Similarity results of Javanese script writing by students with visual impairments at SLB Negeri Semarang

Dissemination

The dissemination of Bagong's Smart has been carried out through school networks, scientific publications, and public exposure to broaden the impact of this inclusive educational innovation. The system can be accessed via regular login at https:// www.bagongsmartadventure.com/, supported by complementary materials in the form of narrated YouTube videos that provide audio-guided instruction. This initiative also received public attention on October 11, 2025, through the IniKampus.id portal, which featured the development of Bagong's Smart and highlighted its commitment to supporting students with visual impairments in their learning. The program's intellectual property rights have been secured through copyright registration under the computer program category in the name of Universitas Negeri Semarang.

The dissemination was conducted through three primary channels: a user guide, public exposure, and intellectual property registration. First, a User Guide was distributed via a narrated YouTube video on the Bagong's Smart channel. This video was released prior to validation and covers basic controls as well as orientation features. Second, Public Exposure was achieved through educational media coverage, specifically an article published by IniKampus on October 11, 2025. Finally, the Intellectual Property for the project has been officially secured under Hak Cipta (Copyright Law No. 28/2014) with Application Number EC002025149880 and Registration Number 000990141, backed by an official certificate of registration.

Based on the results of the trial of the Bagong's Smart website involving six students with visual impairments at SLB Negeri Semarang, the average scores for each assessment aspect of the students' Javanese script writing were identified. The evaluation results indicate that the highest average level of success was achieved in the aspect of stroke direction and sequence, with a mean score of 91.1%. In contrast, the lowest average level of success was observed in the character proportion aspect, with a mean score of 66.7%. A summary of the evaluation results for each aspect of Javanese script writing is presented in Figure 12.

Overall, the Javanese script writings produced by students with visual impairments exhibited basic forms similar to complete Javanese graphemes. The pattern-based approach implemented on the Javanese script website significantly improved the writing performance of visually impaired students, both with and without audio guidance. The Mbata Sarimbag model of Javanese script facilitated the mapping of Javanese grapheme patterns. Its cubistic form received positive responses from students with visual impairments, who perceived the Javanese graphemes as simpler than their original forms. However, the proportion of accurately formed Javanese graphemes remained relatively low, as some students still required further adjustment and practice in writing complete Javanese script forms.

Students' interest can be observed through their enjoyment and increased attention to learning activities (Rakhmawati & Dewanto, 2025). Through learning activities on the Bagong's Smart website, students with visual impairments enjoyed themselves and developed greater curiosity about the various Javanese script patterns presented there. This indicates that the Bagong's Smart website has the potential to foster interest in learning Javanese script among students with visual impairments. This finding is consistent with Abbas et al. (2024), who stated that interest refers to feelings of liking, enjoyment, and enthusiasm toward an object or activity without external influence, thereby generating a strong tendency of attraction or deep desire toward that object or activity. Interest is also closely related to an individual's feelings, goals, and activities (Meke et al., 2019).

The students' enthusiasm was reflected in their active participation while learning through the Bagong's Smart website, such as persistently practicing and repeatedly writing Javanese script without becoming bored until they were able to memorize the patterns of each character. The growing interest in learning Javanese script can help students with visual impairments improve their literacy in Javanese script, particularly by mastering a full range of authentic Javanese graphemes. This finding confirms that the development of learning interest influences students' engagement, their

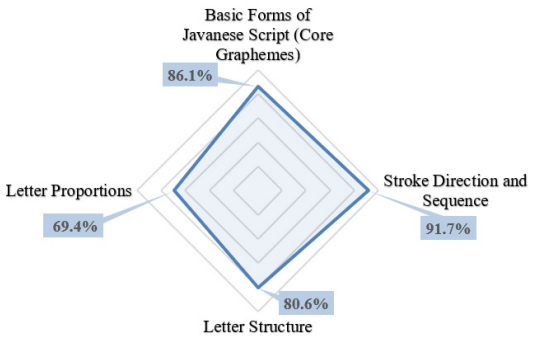

Figure 12. Percentage comparison of the assessment for each aspect of Javanese script writing similarity

ability to explore problems, and their academic achievement (Phuc et al., 2026).

Furthermore, the implementation of the website platform increased students' interest in learning and practicing Javanese grapheme writing, which had previously been perceived as difficult to master. These findings are consistent with the study by Dewi et al. (2026), which reported that the use of digital media significantly enhances students' interest in learning compared to conventional learning media.

The experiential learning model plays an important role in increasing students' enthusiasm and motivation to learn through their direct involvement in the learning process (Kong, 2021). In addition, presenting learning activities as game-based challenges enhances students' creativity and active engagement during the learning process (Alotaibi, 2024). The game-based challenge learning model is also effective in improving students' academic achievement, motivation, and skills (Yüceyurt & Yaş, 2026). Therefore, the integration of an experiential learning model based on game-based challenges for Javanese script learning through the Bagong's Smart website has proven to be potentially effective in improving the ability of students with visual impairments to recognize and write the original graphemes of Javanese script.

The Bagong's Smart website provides a significant positive impact in introducing and improving Javanese script literacy skills among students with visual impairments. With broader, more flexible access, students with visual impairments can learn to write original Javanese script graphemes at any time, anywhere, to meet their learning needs. In addition, the Bagong's Smart website offers the potential to provide higher-quality learning experiences, helping students develop comprehensive skills in writing Javanese script graphemes. Therefore, website-based learning has been shown to improve learning quality, motivation, and flexibility in learning, both in space and time, while also fostering students' self-confidence in the learning process (Bashori et al., 2022; Camilleri & Camilleri, 2023).

■ CONCLUSION

The Bagong's Smart website is an interactive digital platform based on experiential learning integrated with audio instructional features, developed to facilitate Javanese script learning for students with visual impairments through voice-based navigation and a fully accessible disability-friendly design. The website assists learners in transitioning from braille-based recognition of Javanese script toward a comprehensive understanding and the ability to write original graphemes, supported by clear audio features, simple navigation, captcha-free access, practical login options (guest and account), a horizontal interface layout, exercise feedback, and compatibility with screen readers such as NVDA. The design phase began with interface development using CorelDRAW and game integration via accessibility-oriented Unity WebGL, applying the Mbata Sarimbag writing model to simplify audio instructions and implementing a stop–go checkpoint system for grapheme practice. The prototype includes material mode, writing mode, and free mode organized into two progressive chapters. Expert validation results indicated a very good category in the material aspect with an average score of 97.32% and a very good category in the media aspect with an average score of 91.17%. A trial implementation involving six visually impaired students at SLB Negeri Semarang showed an average mastery level of 81.9%, indicating that the website has the potential to help students recognize and write original Javanese script graphemes, even though they previously lacked these skills.

In addition to serving as an inclusive and interactive learning medium, this website is expected to be used for learning the Javanese script in both special and regular schools, particularly across Java. The Bagong's Smart website also supports the preservation of Javanese culture through an adaptive and educational technological approach. Therefore, future research is expected to develop more practical and adaptive digital learning media to facilitate students with visual impairments in writing Javanese script, while also designing technological innovations that support Javanese script typing skills for the visually impaired community. Such developments are expected to broaden the active participation of individuals with visual impairments in preserving Javanese script in an inclusive and sustainable manner.

■ DISCLOSURE OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES

During the writing of this manuscript, the author(s) employed ChatGPT to assist with English proofreading and sentence refinement. The author(s) have reviewed and edited the content generated by this tool and assume full responsibility for the content of the published article.

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