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Development of Flashcard Learning Media Based on QR Video to Improve Understanding of Statistics in Grade XII Deaf Students in Inclusive School

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Abstract: *Students with hearing impairments often face challenges in understanding abstract mathematical concepts, which highlights the need for accessible and visually oriented learning media. This study aims to develop QR video-based flashcard media to enhance the learning process of Statistics for Grade XII deaf students at SLB Kemala Bhayangkari 2 Gresik. The research employed the ADDIE development model (Analyze, Design, Develop, Implement, and Evaluate) and examined the media's feasibility, attractiveness, and effectiveness in improving student learning outcomes. Data was collected using expert validation sheets, teacher and student response questionnaires, and pretest-post test instruments. The results showed that the average validation score reached 97,7%, categorized as highly feasible. Teacher and student responses achieved 96% and 92%, respectively, indicating very positive perceptions. Furthermore, the average pretest score of 40 improved to 100 in the posttest, resulting in an N-Gain value of 100% in the very high category. These findings demonstrate that QR video-based flashcards are not only effective and engaging but also pedagogically appropriate for supporting the learning needs of deaf students. The study concludes that integrating accessible digital media can significantly strengthen inclusive learning environments and encourages future research to explore wider classroom applications and cross-subject implementations. This study contributes a novel QR-based hybrid instructional system that integrates physical flashcards and sign-supported video explanations to enhance inclusive Statistics learning for deaf students.*

Keywords: *deaf students, QR video-based flashcards, inclusive education, statistics learning, learning media development*

Introduction

Inclusive education aims to ensure equal access to learning opportunities for all students, including those with disabilities. Among them, deaf students experience significant challenges in understanding auditory information, which affects their ability to follow verbal instruction and abstract reasoning,

particularly in subjects such as Mathematics and Statistics. These difficulties often arise from limited language acquisition and restricted access to auditory-based explanations, making visual and interactive learning approaches essential (Santos & Cordes, 2022; Langdon et al., 2023).

In the context of Statistics education, deaf learners frequently encounter obstacles in grasping symbolic and abstract representations such as mean, median, and mode. This situation necessitates the development of instructional media that can bridge abstract concepts with concrete visual representations (Dwi Pamungkas et al., 2023). Visual media, especially when integrated with digital and multimodal elements, provide more effective learning pathways for deaf students because they rely heavily on visual-spatial processing and sign-supported communication (Hidayah et al., 2023; Fadlih et al., 2023).

Previous studies have demonstrated that technology-based visual learning tools, such as digital flashcards and QR code media, significantly enhance students' understanding and motivation (Afiyah & Sutriyani, 2024; Ariyanti, 2022). However, research specifically focusing on the use of QR video-based flashcards for deaf students in learning Statistics remains limited. This gap underscores the need for developing media that are not only accessible but also contextually relevant to the communication characteristics of deaf learners.

Globally, inclusive education frameworks emphasize the role of adaptive digital learning tools to reduce barriers faced by students with sensory impairments. International initiatives, such as the United Nations' Sustainable Development Goal 4 (SDG 4), call for equitable and quality education supported by accessible technology. In a mathematics classroom, this translates into the integration of high visibility learning resources, multimodal content delivery, and instructional materials that accommodate diverse perceptual needs. Ideally, deaf students should have access to learning environments that provide explanations through visual narration, signed communication, and interactive representations. However,

this ideal condition is still far from being fully realized in many educational settings.

Recent global research has also highlighted the effectiveness of QR-assisted media in improving engagement and comprehension among learners with different needs. QR-linked instructional videos allow students to revisit explanations independently, reduce dependency on teachers, and encourage self-paced learning. Studies in various countries have shown that embedding video-based scaffolding within printable materials increases retention and understanding of mathematical concepts. Nevertheless, the existing literature has rarely examined how these tools function specifically for deaf learners, whose cognitive processing patterns and communication modalities differ significantly from those of hearing students.

At the local level, preliminary observations and teacher interviews at SLB Kemala Bhayangkari 2 Gresik revealed that Statistics is one of the subjects where deaf students show low conceptual mastery, particularly when dealing with symbolic notation and abstract reasoning. The school had limited availability of structured visual teaching media, and teachers relied mostly on manual drawings, improvised representations, or minimal textual explanations. Students reported difficulties in interpreting textbook content because visual aids were insufficient and explanations were not consistently supported by sign language. These conditions create an urgent need for media that combine clear visual representation, signed explanations, and independent accessibility elements that QR video-based flashcards are designed to provide.

Unlike previous studies that focus on visual learning media or QR-based learning tools separately, this research proposes an integrated instructional system combining printed flashcards, QR codes, and sign language-supported instructional videos specifically for Statistics learning among deaf students. Previous research has emphasized digital flashcards or visual media to increase engagement and motivation yet has not embedded QR-linked instructional videos into a structured flashcard-based

learning flow tailored to deaf learners' cognitive and communication characteristics.

The novelty of this study lies in its system-level instructional design, where QR technology functions not merely as an access feature but as a core pedagogical bridge connecting static visual representations with dynamic, sign-supported explanations. This design enables independent, repeatable, and visually dominant learning experiences that are particularly suited for abstract statistical concepts.

Therefore, this study aims to develop and validate QR video-based flashcard media as an inclusive learning tool to support the mastery of Statistics concepts for deaf students in senior high school. The product integrates printed flashcards with QR-linked instructional videos containing visual explanations and sign language, enabling multimodal engagement and improved learning comprehension.

Method

This research employed a Research and Development (R&D) approach using the ADDIE model (Analyze, Design, Develop, Implement, and Evaluate) as the development framework, which continues to be widely applied in recent educational media development studies (Waldan & bin Abdullah, 2024; Silitonga et al., 2022; Firdaus & Firdaus, 2024; Rustandi & Darmawati, 2025; Najuah et al., 2019). The ADDIE model was selected because it provides a systematic, iterative process that ensures instructional products are valid, effective, and feasible for implementation in real classroom contexts.

Research Subjects and Setting

The study was conducted at SLB Kemala Bhayangkari 2 Gresik, involving Grade XII deaf students selected through purposive sampling. The sampling criteria focused on students who had demonstrated foundational mathematical skills but continued to experience difficulties in statistical reasoning(Anton Marsudiharjo, 2013). To ensure clarity and transparency

in the selection process, the detailed characteristics of the research subjects are presented in Table 1.

Table 1. Characteristics of research subject selected through purposive sampling

Criteria Category	Description	Rationale for Inclusion
Grade Level	Grade XII	Students at this level have a basic math foundation needed for Statistics.
Type of Disability	Deaf / Hearing Impairment	Media specifically targets the visual learning needs of deaf students.
Communication Mode	Sign language + written prompts	Matches the QR-video design containing visual and sign-supported explanations.
Academic Background	Basic mathematical competency established	Required to follow Statistics material (mean, median, mode).
Identified Learning Difficulty	Difficulty with abstract/symbolic statistical concepts	Represents the problem this media aims to solve.
Class Size	5 students	Actual population in Grade XII at the research site.
School Context	SLB Kemala Bhayangkari 2 Gresik	Limited visual digital media availability in Statistics lessons.

Development Procedure

Analyze Phase

During the Analyze phase, the researcher identified gaps between ideal learning conditions and actual classroom practices experienced by deaf students. This process began with a review of educational policy documents, scientific journals, and statistical reports related to the education of students with hearing impairments in Indonesia. The review indicated that deaf students still have limited access to learning media that adequately support visual learning and communication needs, particularly in Mathematics instruction.

To validate these findings, direct classroom observations were conducted during Mathematics lessons at SLB Kemala Bhayangkari 2 Gresik. The observations revealed that both teachers and students encountered difficulties in delivering and understanding abstract mathematical concepts, especially in Statistics. Instructional practices relied heavily on verbal explanations and textbook-based materials, which were not optimally supported by visual or sign-based learning media.

Further analysis was carried out through classroom observations and interviews with the mathematics teacher teaching Grade XII deaf students. The results showed that students experienced significant challenges in comprehending abstract concepts through verbal explanations alone and demonstrated a strong preference for visual stimuli. Students were more responsive to concrete visual representations, animations, and simplified textual explanations. Therefore, instructional media needed to emphasize strong visual elements, concrete representations of statistical concepts, and the use of sign language or simple supporting text to facilitate understanding.

In addition to learner analysis, a resource analysis was conducted to identify the feasibility of media development. Available resources included the existing Mathematics curriculum used at SLB Kemala Bhayangkari 2 Gresik, media development tools such as Canva, hardware including computers, projectors, and smartphones, as well as human resources such as Mathematics teachers. The availability of these resources supported the implementation of visual-based learning media integrated with digital content.

Based on the validated learning gaps, learner characteristics, and resource availability, the minimum functional requirements of the developed media were defined as follows: (1) the media must present statistical concepts through clear and strong visual representations; (2) instructional explanations must be delivered through video content containing animations, illustrations, and sign-supported communication; (3) the media must allow students to access learning materials independently and

repeatedly through QR codes; and (4) the media must be flexible for both teacher-guided instruction and independent classroom use.

Based on the need analysis, a conceptual model of the QR video-based flashcard media was formulated to illustrate the relationship between learners, learning media, QR access, and instructional videos. The conceptual model of the developed system is presented in Figure 1.

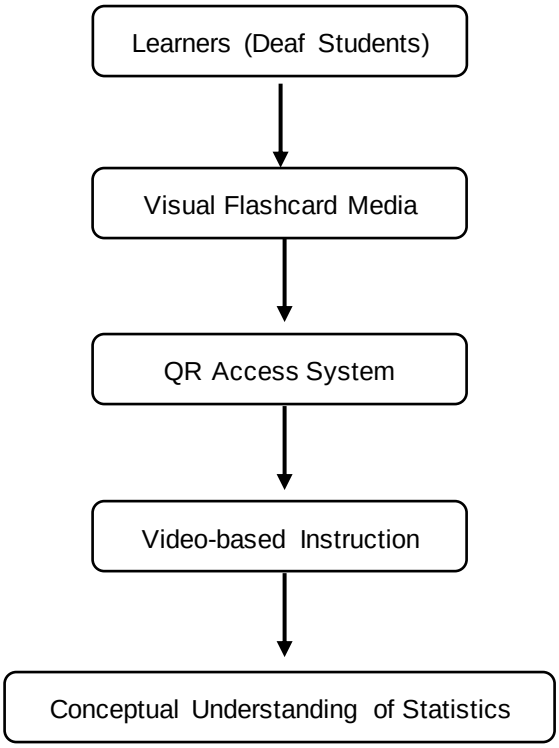

Figure 1. Conceptual model

Design Phase

Based on the results of the needs analysis and the defined minimum functional requirements, the Design phase focused on planning the instructional structure and system architecture of the QR video-based flashcard media. This phase emphasized instructional content design, preparation of video scripts and storyboards, and formulation of the conceptual and procedural models of the learning system.

The instructional content design involved selecting key statistics topics aligned with the senior high school curriculum and adapting them to the learning characteristics of deaf students. Each statistical concept was translated into concise instructional units suitable for visual presentation. The explanations were designed to minimize verbal dependency and prioritize visual clarity, supported by simple text and sign-language elements.

To describe how the media operates in the learning process, a procedural model was developed to represent the sequence of student interaction with the QR video-based flashcards. The procedural learning flow is illustrated in Figure 2.

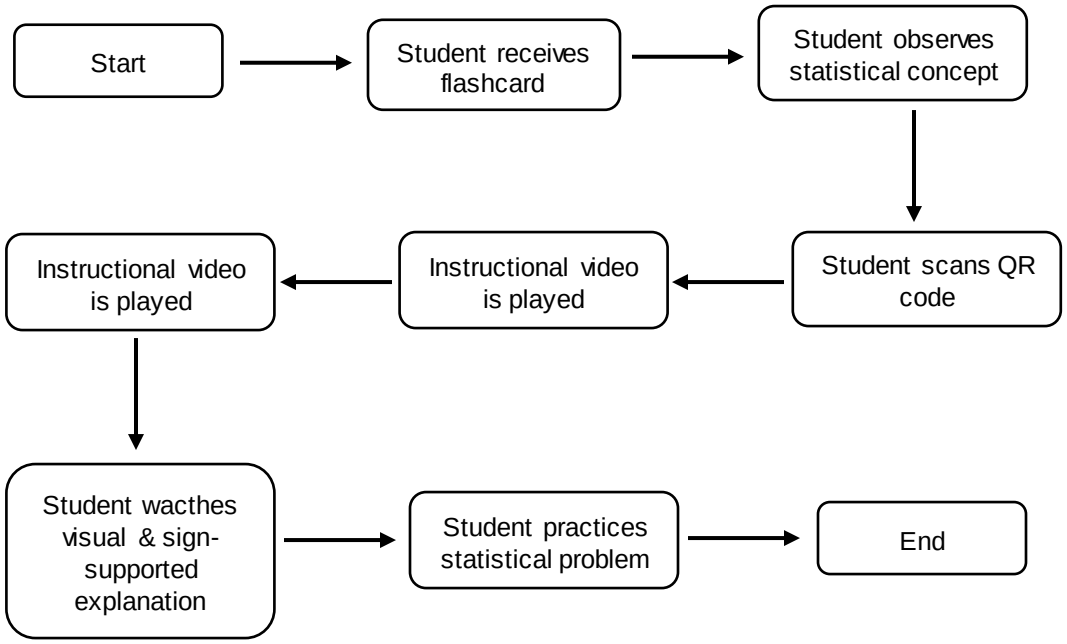

Figure 2. Procedural model

To operate the instructional content, video scripts and storyboards were developed as the main design outputs. The scripts detailed the sequence of explanations, visual cues, and sign-supported communication to be delivered in each video. The storyboards illustrated the flow of visual elements, including animations, illustrations, text highlights, and transitions between scenes. These storyboards served as design blueprints for video production and ensured that abstract statistical concepts were transformed into concrete and visually accessible representations.

Based on the instructional design, a conceptual model of the system was formulated to describe the interaction between learners, media, and digital content. The system consists of deaf students as users, printed flashcards as visual learning prompts, QR codes as access points, and instructional videos as the main explanatory medium. The flashcards provide visual cues for statistical concepts, while the QR codes connect learners to video explanations containing animations, illustrations, and sign-supported instruction. This integration enables a cohesive learning system that bridges physical learning media and digital instructional content.

In addition, a procedural model was designed to describe the workflow of the learning system. The learning process begins with students observing the printed flashcard presenting a statistical concept. Students then scan the embedded QR code using a mobile device, which directs them to the corresponding instructional video. After viewing the video explanation, students apply the concept through guided exercises facilitated by the teacher or through independent learning activities. This procedural design supports both teacher-guided instruction and self-paced learning, allowing students to revisit the instructional content as needed. The outputs of the Design phase, video scripts, storyboards, and system models served as the foundation for the Development phase, where the instructional videos and QR video-based flashcard media were produced and refined.

Development Phase

The development phase represents a critical stage in transforming instructional media design into a functional and testable product. This phase involved content production, selection, and development of supporting media, preparation of user guidelines, formative revisions, and limited trials of the developed QR video-based flashcard media.

The first step in this phase was content development. Statistical learning materials were structured into visually oriented content consisting of images, concise textual explanations, animated videos, and sign language support tailored to the characteristics of Grade XII deaf students.

The content development was guided by the mathematics curriculum implemented at SLB Kemala Bhayangkari 2 Gresik, the results of the needs analysis, and relevant instructional references. Emphasis was placed on presenting abstract statistical concepts in concrete visual forms to facilitate comprehension and reduce cognitive barriers for deaf learners.

Following content development, supporting media were designed and produced. The primary medium consisted of printed flashcards that emphasized strong visual elements, each representing a single statistical concept or problem. To enhance accessibility and independent learning, each flashcard was integrated with a QR code that links directly to a short instructional video. These videos provide visual demonstrations, simplified written explanations, and sign language interpretation, enabling students to access learning materials through multimodal visual channels. In addition, a user guide for teachers was developed to support effective classroom implementation. The guide includes instructions for using the flashcards, recommended usage duration, and examples of classroom integration aligned with lesson objectives.

Formative revisions were conducted based on expert validation involving content experts and media experts. The validation process focused on assessing content accuracy, visual design quality, clarity of presentation, and the relevance of the media to the learning characteristics of deaf students. Feedback from the experts served as the basis for refining visual layouts, adjusting text size, and improving the clarity of instructional elements to enhance usability and instructional effectiveness.

As the final step of the development phase, a limited trial of the revised media was conducted to obtain initial user responses from teachers and students. This trial aimed to evaluate the practicality, clarity, and attractiveness of the media, as well as to identify aspects requiring further improvement before broader implementation. The results of the limited trial provided essential insights into user interaction with the media and informed the readiness of the product for the implementation stage.

To illustrate the developed product, samples of the QR video-based flashcard features are presented in Figure 3, including an example of the printed flashcard design, a screenshot of the instructional video content, and an illustration of the QR code scanning process that directs users to the video-based learning material.

Figure 3. Visual-based flashcard design video with visual & sign language support

Figure 4. QR code scanning flow directing to video content

Figure 3. Sample features of the developed qr video-based flashcard media

Implement Phase

The implementation phase was conducted through limited classroom trials to evaluate the usability, practicality, and initial effectiveness of the QR video-based flashcard media in an authentic learning environment. The trial was carried out at SLB Kemala Bhayangkari 2 Gresik and involved five Grade XII deaf students, one Mathematics teacher, and the researcher as an observer. The selected students represented the target users of the developed media and participated directly in the learning process.

The QR video-based flashcard media was used during the regular classroom learning activities and functioned as the main learning media, not merely as a supplementary tool. The flashcards contained learning materials that had been adjusted to the students' characteristics and curriculum needs, allowing students to access explanations, examples, and practice guidance directly through the media. The implementation was conducted over two learning sessions, each with distinct instructional objectives aligned with the Statistics curriculum.

During the first meeting, learning activities focused on basic statistical concepts, including the definition and formula of mean, media, and mode. The teacher introduced QR video-based flashcard media and demonstrated how to scan the QR codes using smartphones to access instructional videos containing visual explanations and sign language support. Students used flashcards as their primary learning resource to observe visual representations of formulas and conceptual explanations while watching the QR-linked videos under guided instruction. This session aimed to establish a foundational understanding and familiarize students with the structure and use of the media.

In the second meeting, learning activities emphasized data processing and the application of statistical formulas. Students used flashcards to analyze simple datasets and practice calculating mean, median, and mode. At this stage, students interacted more independently with the media, using the QR-linked videos to reinforce procedural understanding and verify calculation steps. The teacher facilitated the learning process by guiding discussions and providing clarification when necessary.

Data collection during the implementation phase was conducted using multiple instruments. Student engagement and media usability were observed throughout both sessions using an observation guide. After the learning activities, students completed a response questionnaire to evaluate the attractiveness, clarity, and ease of use of the media. The teacher also completed a response questionnaire to assess the practical and instructional suitability of the flashcards. In addition, pretest and posttest instruments were administered before and after the implementation to measure changes in students' learning outcomes. This implementation phase provided empirical evidence of how the QR video-based flashcard media supported both conceptual understanding and procedural application of Statistics concepts among deaf students.

Evaluate Phase

The evaluation phase was conducted to measure students' understanding of the learning materials and to assess the appropriateness, attractiveness, and effectiveness of the developed QR video-based flashcard media. Evaluation was carried out using multiple instruments to obtain comprehensive data on both learning outcomes and user perceptions.

The evaluation instruments consisted of a pretest, student worksheets, student response questionnaires, and a posttest. The pretest was administered prior to the learning activities to measure students' initial understanding of statistical concepts. Both the pretest and posttest were designed in the form of multiple-choice questions aligned with the learning indicators of mean, median, and mode.

During the learning process, student worksheets (LKM) in the form of essay questions were used to evaluate students' understanding after receiving the instructional materials and using the QR video-based flashcard media. The worksheets required students to process data and apply statistical formulas, allowing the researcher to assess conceptual and procedural understanding.

To evaluate the attractiveness and user satisfaction of the media, a student response questionnaire was administered after the completion of the learning sessions. The questionnaire employed a five-point Likert scale (1–5) to measure students' perceptions regarding ease of use, clarity of visual presentation, learning engagement, and overall satisfaction with the media.

The posttest was administered at the end of the final meeting as a summative assessment to determine whether there was an improvement in students' understanding after using the media. The results of the pretest and posttest were compared to evaluate learning improvement, and the effectiveness of the media was determined based on the increase in students' scores. To clarify the evaluation procedures, Table 1 presents the instruments used in this study along with their purposes and administration stages.

Table 1. Evaluation instruments used in the study

Instrument	Purpose	Form	Scale / Scoring	Time of Administration
Pretest	Measure students' initial understanding of Statistics concepts (mean, median, and mode)	Multiple-choice questions	Score-based	Before the learning activities
Student Worksheet (LKM)	Assess students' conceptual and procedural understanding after using the media	Essay questions	Rubric-based	After the learning session
Student Response Questionnaire	Measure students' satisfaction, attractiveness, and ease of use of the media	Questionnaire	Likert scale (1–5)	After media use
Posttest	Measure improvement in students' learning outcomes	Multiple-choice questions	Score-based	At the final meeting

The evaluation procedures enabled the researcher to systematically assess the learning media from cognitive, affective, and usability perspectives, providing empirical evidence of its effectiveness in improving students' understanding of Statistics.

Data Collection Instruments

Data were collected using three instruments: Expert Validation Sheets, assessing content accuracy, design quality, and pedagogical suitability. Questionnaires for teachers and students to measure the attractiveness and usability of the media. Pretest and Posttest Instruments to evaluate learning effectiveness.

Data Analysis Techniques

Quantitative data from validation and response sheets were analyzed using descriptive statistics, expressed in percentages. The effectiveness of the

media was determined by the N-Gain score, calculated using the formula proposed by Hake (1999):

$$N - \text{Gain} = \frac{(Posttest - Pretest)}{(100 - Pretest)} \text{ x } 100\%$$

The interpretation of N-Gain followed the standard categories:

Score (%)	Category
76% - 100%	Very High
56% - 75%	High
41% - 55%	Medium
26% - 40%	Low
0% - 25%	Very Low

Results

Expert Validation Results

The QR video-based flashcard media was evaluated through an expert validation process involving three validators, namely a content expert, a media expert, and an instructional design expert. The validation data were collected using expert validation sheets to assess the appropriateness of the media in terms of content accuracy, visual design, and instructional structure.

The content expert provided a validation score of 100%, indicating that the statistical material presented in the media was accurate and aligned with the curriculum. The media expert gave a score of 88.6%, reflecting that the visual layout, QR code integration, and video presentation were highly appropriate, although minor revisions were suggested regarding text size and the reduction of redundant graphics. The instructional design expert awarded a score of 100%, confirming that the instructional flow and learning structure were suitable for deaf students.

Based on the expert assessment results obtained through the validation sheets, the overall average validation score reached 97.7%, which falls into the highly feasible category. These results indicate that the developed media met the required pedagogical and technical standards for classroom implementation.

Teacher and Student Responses

Teacher and student response data were collected after the implementation phase using response questionnaires to evaluate the attractiveness and practicality of the QR video-based flashcard media. The teacher response questionnaire resulted in an average score of 96%, categorized as very positive, indicating that the media was perceived as practical and suitable for classroom instruction.

Student responses yielded an average score of 92%, also categorized as very positive. These data indicate that students found the media visually clear, engaging, and easy to use during the learning process. In particular, the QR-linked videos were reported to support understanding by providing visual explanations and sign language assistance. The summary of teacher and student responses is presented in Table 2.

Table 2. Teacher and student response results

Respondent	Average Score (%)	Category
Teacher	96	Very Positive
Students	92	Very Positive

Learning Outcomes (Pretest–Posttest Results)

Students' learning outcomes were evaluated using a one-group pretest–posttest design. Pretest data were collected before the learning activities to measure students' initial understanding of statistical concepts. The results showed an average pretest score of 40, indicating limited initial mastery.

After the implementation of the QR video-based flashcard media, a post test was administered as a summative assessment. The posttest results showed an average score of 100, demonstrating a substantial improvement in students' learning outcomes. The comparison between pretest and posttest scores indicates a clear increase in students' understanding of mean, median, and mode.

The improvement in learning outcomes was further analyzed using the N-Gain formula. The results showed an N-Gain value of 100%, which falls into the very high effectiveness category. These findings indicate that the use of the QR video-based flashcard media was effective in improving students' statistical understanding. The comparison of pretest and posttest scores is illustrated in Figure 3.

Table 3. Pretest–Posttest Results and N-Gain Score

Test Type	Mean Score	N-Gain (%)	Category
Pretest	40	-	-
Posttest	100	100	Very High

Discussion

The discussion of this study is based on data obtained from expert validation, response questionnaires, and learning outcome evaluations conducted during the implementation of the QR video-based flashcard media. The expert validation results indicate that the developed media is highly feasible for instructional use. This is evidenced by an average validation score of 97.7%, obtained from assessments by content, media, and instructional design experts. The perfect scores given by the content and instructional design experts demonstrate that the statistical material and learning structure were appropriate for Grade XII deaf students, while the media expert's score of 88.6% reflects strong visual quality and QR integration with minor technical refinements. These results confirm that the media meets pedagogical and technical standards required for inclusive learning environments.

The attractiveness and practicality of the media are supported by the response data collected from teachers and students. The teacher response score of 96% indicates that the media was practical to implement and aligned with instructional objectives, while the student response score of 92% reflects high levels of engagement and satisfaction during learning activities. These findings suggest that the visual layout, QR-linked videos, and sign language support successfully facilitated student interaction with the learning materials, as reflected in the consistently high response percentages.

The effectiveness of the QR video-based flashcard media is demonstrated by the learning outcomes data. The average pretest score of 40 increased to 100 in the posttest, resulting in an N-Gain value of 100%, which falls into the very high category. This substantial improvement indicates that the media effectively supported students' understanding of statistical concepts, including mean, median, and mode. The improvement aligns with the structured use of the media across two learning sessions, which gradually progressed from conceptual understanding to procedural application.

The findings of this study suggest that the integration of QR-linked instructional videos within flashcards provides effective visual scaffolding for deaf students, as evidenced by the high validation scores, positive responses, and significant gains. The data collectively indicates that the media functioned not only as an attractive learning tool but also as an effective instructional system supporting inclusive Statistics learning.

Despite these positive results, the study has limitations. The number of research subjects was limited to five students, and the implementation was conducted in a single educational setting. Therefore, the findings should be interpreted within this context. Future research is recommended to involve a larger sample size, extend implementation across multiple schools, and incorporate interactive or adaptive features to further enhance learning effectiveness.

Conclusion

This study concludes that the QR video-based flashcard media developed through the ADDIE model is feasible, attractive, and effective for teaching Statistics to deaf Grade XII students. The feasibility of the media is supported by expert validation results, which yielded an average score of 97.7%, indicating that the content, visual design, and instructional structure met the required pedagogical standards for inclusive learning.

The attractiveness and practicality of the media are evidenced by the response data collected from users. Teacher responses reached 96%, while student responses reached 92%, both categorized as very positive. These results indicate that the media was easy to use, visually clear, and engaging, and that the integration of QR-linked videos with visual explanations and sign language supported students' learning experiences during classroom instruction.

The effectiveness of the media in improving learning outcomes is demonstrated by the comparison of pretest and posttest results. The average pretest score of 40 increased to 100 in the posttest, resulting in an N-Gain value of 100%, which falls into a very high category. This finding confirms that the QR video-based flashcard media significantly improved students' understanding of statistical concepts, including mean, median, and mode.

Overall, the findings indicate that the developed media functioned not only as an engaging learning tool but also as an effective instructional system that supports inclusive Statistics learning for deaf students. Although the study was limited to a small number of participants and a single educational setting, the results provide empirical evidence of the potential of QR-based visual learning media to enhance conceptual understanding in special education contexts. Future research is recommended to expand the implementation to broader populations, integrate interactive or adaptive features, and explore its application in other subject areas.

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