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Development Of Web-Based Interactive Audio Media For Understanding The Human Digestive System In Science Learning For Students With Visual Impairments

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Abstract

This study aimed to develop web-based interactive audio media for learning the human digestive system in Science for students with visual impairments; determine its feasibility in terms of content and media; examine its practicality based on teacher and student responses; and evaluate changes in students' understanding after its use. This research and development study adopted Thiagarajan's 4-D model, comprising Define, Design, Develop, and limited Disseminate stages. The study was conducted at MTs LB/A Yaketunis and involved one Science teacher and 12 students with visual impairments (seven students in Grade VIII and five in Grade IX). Data were collected through interviews, expert-validation forms, teacher and student response questionnaires, and pretest–posttest items. Descriptive quantitative analysis was used to assess feasibility and practicality, while the Shapiro–Wilk test and Wilcoxon Signed Rank Test were used to examine learning outcomes. The resulting product, technically named LMS-IPA, is a website with a Learning Management System structure, audio explanations, audio-based interactive quizzes, spoken feedback for incorrect answers, learning-progress information, and a teacher administration page. Content validation reached 81 of 90 (90%), while media validation reached 98 of 115 (85.2%); both were categorized as highly feasible. Teacher responses reached 88%, and the mean student response was 90.2%, both in the highly feasible category. Mean test scores increased from 53.33 on the pretest to 90.00 on the posttest. The Wilcoxon test showed a significant difference (Asymp. Sig. = 0.002), and the mean normalized gain was 0.8182 (81.82%), categorized as high. These findings indicate that LMS-IPA was feasible and practical and was

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accompanied by improved understanding in this limited trial.

Keywords: interactive audio learning media; web-based learning; visual impairment; human digestive system; 4-D model

INTRODUCTION

Learning media serve as a means of conveying instructional messages and supporting learners' attention, understanding, and participation. In instructional settings, media connect information sources with learners and can present content in forms that are more accessible to users (Arsyad, 2017; Smaldino et al., 2019). For students with visual impairments, the selection and design of media require particular attention because learning resources that depend heavily on visual information may create barriers to accessing concepts and instructional activities.

Digital technology can provide alternative access to learning materials when its design considers users' accessibility requirements. Universal Design for Learning emphasizes providing multiple means of representation, engagement, and action and expression (CAST, 2018). Web accessibility guidance also highlights the importance of perceivable, operable, understandable, and robust content, including compatibility with assistive technologies such as screen readers (W3C, 2018, 2023). These principles are relevant to the development of learning media for students with visual impairments, especially when the material is presented through a website.

Audio is an important modality for making instructional information accessible to learners who cannot rely on visual presentation. Multimedia learning principles emphasize the organization and segmentation of information to support processing and reduce unnecessary cognitive demands (Mayer, 2021; Mayer & Moreno, 2003; Sweller et al., 2011). In this context, audio narration, clear navigation, and spoken feedback can support access to content and interaction with learning activities. However, the media must be designed not merely as a collection of audio files but as a structured learning environment that enables learners to access material, complete activities, and monitor their learning progress.

Previous studies cited in the thesis have examined digital and interactive learning media for learners with disabilities and the use of audio or accessible digital resources. Dhuha and Astutik (2025) discussed accessible digital learning media for students with special needs, while Astuti et al. (2023) examined interactive web-based learning for blind and deaf students in higher education. Research on audio-assisted resources has also highlighted their potential contribution to access for learners with visual impairments (Rafikayati et al., 2020; Sudarma et al., 2024). Other

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development studies have explored tactile-audio learning resources and accessible mobile applications (Amran et al., 2025; Pamuji et al., 2022). These studies provide a relevant foundation, although their products, subject matter, and learning contexts differ from the present development.

The human digestive system is a Science topic involving organs, processes, and relationships that are commonly represented through diagrams and other visual materials. For students with visual impairments, learning this topic requires an alternative presentation that communicates the sequence and function of digestive organs without depending exclusively on visual representations. The thesis identifies the need for media that can be accessed using a screen reader, navigated through a mobile phone or keyboard, provides clear audio explanations, includes interactive exercises, and supports independent learning.

To address these needs, this study developed web-based interactive audio media for understanding the human digestive system in Science learning for students with visual impairments. The product was designed as a website with a Learning Management System (LMS) structure and was technically named LMS-IPA. The development process was guided by the 4-D model (Thiagarajan et al., 1974), while product quality was considered in terms of validity, practicality, and effectiveness (Nieveen, 1999). Understanding of the learning material was assessed through learning indicators informed by the revised taxonomy of educational objectives (Anderson & Krathwohl, 2001).

Accordingly, this study had four objectives: (1) identify the needs underlying the development of web-based interactive audio media for the human digestive system; (2) determine product feasibility from content and media perspectives; (3) examine practicality based on teacher and student responses; and (4) examine changes in students' understanding following the use of the developed media.

METHODS

Research Design

This study employed a Research and Development approach by adapting Thiagarajan et al.'s (1974) 4-D development model. The model consists of Define, Design, Develop, and Disseminate stages. In this study, dissemination was conducted on a limited basis, while the main development and evaluation activities focused on the first three stages.

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Setting and Participants

The research was conducted at MTs LB/A Yaketunis. The product trial involved one Science teacher who taught Grades VII, VIII, and IX and 12 students with visual impairments. The student participants consisted of seven Grade VIII students and five Grade IX students. Participants were selected purposively in accordance with the criteria described in the thesis, including students who had not yet mastered the human digestive system material.

Sampling and Eligibility

The trial participants were selected using purposive sampling based on predetermined criteria. For the teacher participant, the criterion was a Science teacher of students with visual impairments whose educational background was in sports education, rather than Science education or special education. For student participants, the criterion was having a visual impairment and not yet having mastered the human digestive system material. Based on the school records reported in the thesis, the field trial involved one Science teacher and 12 students with visual impairments: five Grade IX students and seven Grade VIII students. The teacher and students were involved in the field trial of the developed website.

Measures

Four data-collection techniques were used in accordance with the development stages: interviews, questionnaires, tests, and observation. The interview guide was used in the Define stage to identify learning needs and was organized into six aspects: technology use, subject matter analysis, evaluation analysis, learning-media needs, teacher needs, and development expectations. The guide contained 19 questions. Questionnaire instruments were used for expert review and user responses. The content validation questionnaire covered four aspects material suitability, conceptual accuracy, material presentation, and usefulness and comprised 18 items. The media validation questionnaire covered five aspects appearance, accessibility, ease of use, functionality, and usefulness with 24 indicators. Both expert validation questionnaires used a five-point Likert scale, from 1 (very poor) to 5 (very good). Teacher and student response questionnaires assessed ease of access, ease of use, accessibility, usefulness, and user satisfaction; the statements were tailored to the respective functions of each user. Learning comprehension was measured through pretest and posttest assessments on the human digestive system. In the pretest, the researcher presented the questions and students wrote their answers in Braille. After using the website, students completed the quiz through the website's interactive quiz feature for

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the posttest. The thesis reports that the test instrument was prepared and validated by experts. Observation was also used during the field trial to record students' responses while using the website.

Development Procedure

The Define stage identified learning needs, student characteristics, teacher needs, the characteristics of the subject matter, and learning objectives. The needs analysis was conducted through an interview with the Science teacher. The findings informed the requirements for accessible navigation, screen-reader compatibility, audio presentation, interactive exercises, and independent access to learning materials.

The Design stage translated the needs analysis into the structure and features of LMS-IPA. The design included the learning content, audio narration, website interface, navigation, interaction, quiz activities, and evaluation instruments. The Develop stage involved product realization, expert validation, revision, and field testing. The product was assessed by a content expert and a media expert. After revisions, it was tried out with the teacher and students. The Disseminate stage was limited to the research site and the preparation of user guidance; broader dissemination to other schools had not been implemented.

Product and Instruments

LMS-IPA is a website organized using an LMS structure. Its main components include a student login and account-registration function, a student home page displaying learning progress, audio-based explanations of the human digestive system, interactive audio quizzes, spoken feedback when an answer is incorrect, and an administration page for the teacher as facilitator. The website was designed for access through laptops, mobile phones, and tablets, with attention to screen reader use and keyboard navigation.

The instruments comprised an interview guide for the needs analysis, expert-validation questionnaires, teacher and student response questionnaires, and pretest–posttest items. The expert validation examined content and media aspects. Teacher and student questionnaires used a five-point response scale. The student response questionnaire covered ease of access, ease of use, accessibility, usefulness, and user satisfaction. Learning outcomes were assessed using pretest and posttest scores.

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Data Analysis

Feasibility and practicality data were analyzed descriptively by converting obtained scores into percentages and interpreting them using the feasibility categories applied in the thesis. Learning outcome data were examined by comparing pretest and posttest scores. The Shapiro Wilk test was used to assess normality; because the data did not meet the normality criterion, the Wilcoxon Signed Rank Test was applied. Normalized gain (N-Gain) was also calculated to describe the magnitude of improvement. The study used a one group pretest and posttest design without a control group; therefore, the results are interpreted within the limits of the trial design.

RESULTS AND DISCUSSION

Needs Analysis and Product Development

The needs analysis indicated that students with visual impairments required learning media that could be accessed using screen-reader technology, navigated through a mobile phone or keyboard, and presented the learning material through clear audio. The media also needed to provide interactive exercises and support students' independent learning when reviewing lessons or completing tasks assigned by the teacher. These requirements became the basis for the development of LMS-IPA.

The product was developed as a website with an LMS structure rather than as a stand-alone audio resource. The student interface provides access to learning content and quizzes and displays overall learning progress. The quiz items are presented through audio, allowing students to listen to questions and select answers. Audio feedback is provided when a response is incorrect. A separate teacher administration page supports the teacher's role as facilitator. The website can be accessed using laptops, mobile phones, and tablets.

Product Feasibility

The product was evaluated by experts in content and media. The content expert assessed material suitability, conceptual accuracy, presentation, and usefulness. The media expert assessed the media and its technical presentation. The content validation obtained 81 out of a maximum score of 90 (90%), while media validation obtained 98 out of 115 (85.2%). Both results were categorized as highly feasible.

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Table 1. Results of Expert Validation of the Developed Media

Assessment aspect	Obtained score	Maximum score	Percentage	Category
Content validation	81	90	90.0%	Highly feasible
Media validation	98	115	85.2%	Highly feasible

The validation results indicate that the product met the feasibility criteria applied in the study. The content assessment supported the suitability of the material on the human digestive system and its alignment with the learning objectives. The media assessment provided an evaluation of the website's design and technical features for the intended users. These results are consistent with the product-quality perspective that considers validity as one of the central criteria in educational development (Nieveen, 1999).

Practicality Based on User Responses

The field trial involved one Science teacher and 12 students with visual impairments. The teacher questionnaire consisted of 16 statements with a maximum score of 80. The teacher obtained a score of 71, equivalent to 88%, which was categorized as highly feasible. The teacher's comments indicated that the language used on the website was relatively clear and understandable and that the screen-reader feature was helpful for students with visual impairments.

The student response questionnaire also consisted of 16 statements. The mean student response was 90.2%. Ten of the 12 students (83.3%) were in the highly feasible category, while two students (16.7%) were in the feasible category. The highest individual percentage was 97%, while the lowest was 72%. Across the assessed dimensions, ease of use obtained 96.67%, user satisfaction 95.83%, usefulness 91.11%, accessibility 90.83%, and ease of access 85.56%. These findings show positive responses while also indicating that some students experienced technical difficulties, including login support needs and differences in preferred audio speed.

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Table 2. Teacher and Student Responses to the Developed Media

User response	Participants	Percentage	Category
Teacher	1	88.0%	Highly feasible
Students	12	90.2% (mean)	Highly feasible

The response data suggest that LMS-IPA was practical for use in the trial setting. At the same time, individual comments and differences in response scores are important for further refinement. In particular, login procedures, audio speed, and the amount of practice should be considered when improving the product. The teacher's role remains important as facilitator, especially when students need initial support in accessing the website.

Effectiveness in Improving Understanding

The effectiveness trial used a one-group pretest–posttest design with 12 students. The mean pretest score was 53.33, while the mean posttest score was 90.00. The score totals were 640 for the pretest and 1,080 for the posttest. The comparison indicates an increase in students' understanding after the learning activities using LMS-IPA.

Table 3. Comparison of Students' Pretest and Posttest Scores

Learning outcome	Pretest	Posttest
Total score	640	1,080
Mean score	53.33	90.00

The Shapiro Wilk test indicated that the pretest data ($p = 0.035$) and posttest data ($p = 0.002$) were not normally distributed. Accordingly, the Wilcoxon Signed Rank Test was used. The test produced an Asymp. Sig. (2-tailed) value of 0.002, which is below 0.05, indicating a statistically significant difference between pretest and posttest scores. The mean N-Gain was 0.8182 (81.82%), categorized as high. The minimum and maximum N-Gain percentages were 50% and 100%, respectively.

The results indicate that students' scores were higher after using the developed media in this limited trial. The audio explanations, interactive quizzes, spoken feedback, and progress information provided structured access to the learning content and opportunities to respond to

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questions. This product design is consistent with the accessibility orientation of UDL (CAST, 2018) and web accessibility guidance (W3C, 2018, 2023). The use of segmented audio and feedback can also be discussed in relation to multimedia learning and cognitive load principles (Mayer, 2021; Mayer & Moreno, 2003; Sweller et al., 2011).

Nevertheless, the effectiveness findings should be interpreted in relation to the one-group design and the limited number of participants at a single school. The results demonstrate a difference between pretest and posttest scores in the trial, but the absence of a comparison group means that the change cannot be attributed exclusively to the product. The study therefore provides preliminary evidence of improvement in the research context rather than evidence of effectiveness across other schools or populations.

DISCUSSION

The findings of this study show that the development of LMS-IPA was closely connected to the learning access needs of students with visual impairments. The needs analysis identified the importance of screen-reader compatibility, keyboard-operable navigation, access through mobile devices, clear audio explanations, and opportunities to practise learning content independently. These requirements indicate that accessibility should not be treated as an additional feature applied after a learning medium has been developed. Rather, accessibility needs to inform the organization of content, interface design, and learning activities from the beginning of the development process. This orientation is consistent with the Universal Design for Learning framework, which emphasizes providing multiple means of representation, engagement, and action and expression to accommodate learner variability (CAST, 2018).

The use of a web-based Learning Management System also provides a way to organize learning resources and activities in one environment. In LMS-IPA, students can access audio-supported explanations, complete interactive quizzes, receive spoken feedback, and monitor their learning progress, while the teacher can use the administrative page to facilitate and monitor learning. The combination of these features is relevant to the needs identified in the study because students require not only access to information but also an organized pathway for interacting with the material. Previous work on accessible digital learning and audio-based learning resources has similarly highlighted the role of technology and audio support in widening access to learning for people with visual impairments (Astuti et al., 2023; Rafikayati et al., 2020). The present product extends this approach by combining learning content, assessment activities, feedback, and progress information within a single web-based platform.

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The presentation of the human digestive system through structured text and audio narration is important because the topic involves a sequence of organs and processes that are often introduced through visual diagrams. For students who cannot rely on visual information, verbal explanations need to communicate the sequence and relationships among concepts clearly. The product therefore uses descriptive explanations and audio narration to make the content accessible without requiring students to interpret visual representations as the primary source of information. The inclusion of quizzes and audio feedback also allows students to check their understanding after engaging with the material. From a multimedia learning perspective, the organization and pacing of information are important considerations when designing learning materials, particularly to avoid placing unnecessary demands on learners' cognitive processing (Mayer, 2021; Sweller et al., 2011).

The expert validation results provide evidence that the product met the feasibility criteria used in this development study. The content validation score was 90%, while the media validation score was 85.2%; both were categorized as highly feasible in the thesis. These results suggest that the developed product was considered appropriate in terms of its learning content and media characteristics by the respective validators. Nevertheless, expert validation represents an assessment of product quality and should be distinguished from evidence of learning effectiveness. In development research, feasibility assessment is one part of evaluating product quality, while user responses and learning outcome data provide additional information about how the product functions in practice (Nieveen, 1999).

The positive responses from the teacher and students further indicate that LMS-IPA was usable in the limited trial context. The teacher response reached 88%, and the mean student response was 90.2%. These results suggest that the platform's access, navigation, content presentation, and learning functions were generally received positively by its intended users. However, the response data also point to aspects that may require further refinement, including login procedures, audio speed, and the amount of content presented. Such feedback is important because a product may be judged feasible by experts while still requiring adjustments to better accommodate differences in users' preferences and technology skills. Accordingly, the results should be interpreted as evidence of practicality in the participating school rather than as proof that the platform will function equally well for all students with visual impairments.

The increase in the mean score from 53.33 on the pretest to 90.00 on the posttest, together with the Wilcoxon result ($p = 0.002$) and the mean N-Gain of 0.8182, indicates that students' measured understanding was higher after using LMS-IPA during the trial. The audio

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explanations, interactive quizzes, and spoken feedback may have supported students in accessing and reviewing the learning material and in identifying errors in their answers. However, because the evaluation used a one-group pretest–posttest design with 12 students at one school and did not include a comparison group, the observed improvement cannot be attributed exclusively to the media. Other factors, such as prior knowledge, instructional support, and familiarity with the test, may also have contributed to the score changes. Therefore, the findings provide promising preliminary evidence of the product's potential, while further testing with a larger sample, additional schools, and a stronger comparison design is needed to establish its effectiveness more broadly.

Limitations

The study had several limitations. First, the trial was conducted at one school and involved one teacher and 12 students, limiting the generalizability of the findings. Second, the needs analysis at the Define stage relied on an interview with the teacher and did not include direct interviews with students or direct classroom observation; consequently, some descriptions of student needs were based on the teacher's perspective. Third, some scanned media-validation documentation contained unclear or duplicate marks and one item without a recorded mark, so the calculation for that aspect involved estimation and exclusion of unclear data. Fourth, dissemination was limited and did not include the planned socialization to Science teachers at other special schools. Finally, the one-group pretest–posttest design did not include a control group.

Future development should expand the learning content, improve access and login support, consider additional audio explanations for complex content, and conduct trials involving more schools and participants. Longitudinal or controlled studies would provide stronger evidence about the longer-term contribution of the media to students' understanding.

CONCLUSION

This study developed LMS-IPA, a web-based interactive audio learning medium for the human digestive system in Science learning for students with visual impairments. The product was designed in response to the need for screen-reader accessibility, keyboard and mobile navigation, clear audio explanations, interactive exercises, and support for independent learning. Expert validation placed the content component at 90% and the media component at 85.2%, both in the highly feasible category. Teacher response reached 88%, while the mean student response

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reached 90.2%, also categorized as highly feasible. In the limited field trial, the mean score increased from 53.33 on the pretest to 90.00 on the posttest; the Wilcoxon test yielded p = 0.002, and the mean N-Gain was 0.8182 (81.82%), categorized as high. These findings indicate that the developed product was feasible and practical and was accompanied by improved student understanding in the trial. Broader claims require further testing with larger samples, additional schools, and stronger research designs.

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