Jurnal Review Pendidikan Dasar:
Jurnal Kajian Pendidikan dan Hasil Penelitian
Vol 12(1), Februari 2026

e-ISSN: 2460-8475
http://journal.unesa.ac.id/index.php/PD
https://doi.org/10.26740/jrpd.v12n1.p1-17

Development of Augmented Reality Learning Media for Classifying Animals by Food Type in Elementary Science

Rossa Ilma Silviah, Nahdlatul Ulama University of Sidoarjo, Indonesia
Novaria Lailatul Jannah, Nahdlatul Ulama University of Sidoarjo, Indonesia
Lailatul Mufidah ✉, Nahdlatul Ulama University of Sidoarjo, Indonesia

✉ lailatulmufidah2905@gmail.com

Abstract: Elementary science lessons on classifying animals by food type often rely on static media that offer limited opportunities for interaction. This study aimed to describe the development of augmented reality (AR) learning media built on the Assemblr Edu platform using the ADDIE model, and to examine whether and how the media meets criteria of validity, practicality, and effectiveness among third-grade students. A research and development design was applied with 16 third-grade students, one material expert, one media expert, and one classroom teacher. The instruments were expert validation sheets, teacher and student response questionnaires, and an evaluation test, and the data were analyzed descriptively as percentages. The material expert and the media expert gave scores of 91.11% and 82.5%, respectively, both in the very valid category. The teacher response reached 91.11% (very practical) and the student response reached 85.63% (practical). A total of 13 of 16 students (81.25%) reached the minimum completion criterion, with a class mean of 83.6, which met the effectiveness criterion set in this study. These findings suggest that the media is feasible for classroom use as a supplement to science instruction, although the small sample, the absence of a comparison group and a pretest, and the delivery of the lesson by the researcher limit generalizability. Future studies should apply pretest-posttest designs with comparison groups, teacher-led implementation, and longer instructional periods.

Keywords: augmented reality; ADDIE model; Assemblr Edu; animal classification; elementary science education.

How to Cite: Silviah, S.R., Jannah, N.L., & Lailatul, M. (2026). Development of Augmented Reality Learning Media for Classifying Animals by Food Type in Elementary Science. *Jurnal Review Pendidikan Dasar: Jurnal Kajian Pendidikan dan Hasil Penelitian*, 12(1), 1-17. https://doi.org/10.26740/jrpd.v12n1.p1-17

© The Author(s) 2026

Article Info:
Received: 29 January 2024; Accepted: September 14, 2024; Published Online: 12 November 2024

Published by:
Elementary Education, State University of Surabaya

INTRODUCTION

Digital technologies are increasingly used to support science instruction, and evidence from classroom studies indicates that their value depends on how they are designed and implemented (Fidan & Tuncel, 2019; Wen et al., 2023). Augmented reality (AR) is one such tool, and it allows learners to view computer-generated three-dimensional objects within the real environment through a digital device. In physics classrooms, an AR application on wave-particle duality was associated with significantly higher self-efficacy and with a stronger inclination toward higher-level conceptions of learning after a four-week intervention (Cai et al., 2021). A quasi-experimental study in university science laboratories likewise found that AR significantly enhanced students' laboratory skills and supported positive attitudes toward physics laboratories after a five-week application (Akçayır et al., 2016). Evidence from the upper elementary level shows a similar direction, as fifth-grade students who read with AR applications achieved higher reading comprehension and learning permanency than students taught with traditional methods (Bursali & Yilmaz, 2019).

Previous studies have examined the educational impact of augmented reality (AR) on achievement, attitudes, motivation, learning skills, and cognitive processing. Fidan and Tuncel (2019) investigated AR in problem-based physics learning, while Sökmen et al. (2024) reported improvements in achievement, participation, and attitudes among fourth-grade students. Wen et al. (2023) found gains in self-directed learning and creative thinking in inquiry-based plant reproduction lessons, although academic performance did not differ significantly with AR use. Thees et al. (2022) showed that learning outcomes and cognitive load varied according to AR display configuration, while Ibáñez et al. (2016) examined scaffolding effects on learning outcomes and behavioral patterns in AR simulations. In science education, AR has improved understanding of the human circulatory system (Gnidovec et al., 2020), conceptual knowledge in university physics laboratories (Altmeyer et al., 2020), and achievement, interest, and science process skills in primary science lessons (Abdullah et al., 2022; Çetin & Türkan, 2022). Similarly, Afnan et al. (2021) reported higher achievement with AR Zoo, Sahin and Yilmaz (2020) found improved achievement and attitudes among seventh-grade students, and Arici and Yilmaz (2025) reported greater achievement and motivation with AR than with video-based learning.

Existing studies have primarily investigated AR effectiveness through comparisons between instructional conditions or measurements of changes in achievement, attitudes, and motivation (Abdullah et al., 2022; Afnan et al., 2021; Çetin & Türkan, 2022; Sökmen et al., 2024). Less attention has been directed toward documenting the staged development of AR media for specific elementary science topics and jointly evaluating expert validity, teacher and student practicality, and student mastery. Limited research has examined this combination for classifying animals by food type, specifically herbivores, carnivores, and omnivores. Within the Merdeka Curriculum (*Kurikulum Merdeka*), this topic is taught in Natural and Social Sciences (*Ilmu Pengetahuan Alam dan Sosial, IPAS)* and requires students to connect animals with their feeding habits. This study therefore develops and evaluates AR-based learning media for animal classification by food type through a structured development process encompassing validity, practicality, and effectiveness.

This issue is relevant to the classroom context of the present study. An interview with the third-grade teacher on December 12, 2024 indicated that the lesson on animal classification by food type relied on posters. The teacher also reported that AR-based media had not been used because of limited facilities and a lack of training, and that not all students understood the material well. Such conditions are consistent with the findings of Alalwan et al. (2020), whose interviews with 29 primary school science teachers identified lack of competency, lack of time, and limited environmental resources as common challenges in the use of AR and virtual reality. Wen et al. (2023) likewise reported that teachers in primary science classrooms raised practical concerns about the time and effort needed to troubleshoot an AR application during lessons. A medium that is practical for teachers and informative for students therefore needs to be evaluated together with its effectiveness.

This study addresses an aspect of AR research in elementary science that has received limited attention by reporting the development and multi-criteria evaluation of an AR learning medium for classifying animals by food type. This study extends previous research by examining AR media built on the Assemblr Edu platform through the ADDIE model within a third-grade science context in Indonesia, and by presenting validity, practicality, and effectiveness evidence together. The novelty of this study therefore lies in the combination of topic, platform, instructional design model, and classroom context,

and the design does not support causal claims. This study aims to describe the development of the AR medium and to examine whether and how it meets criteria of validity, practicality, and effectiveness.

The study is guided by the following research questions: 1) How is AR-based learning media on animal classification by food type developed through the stages of the ADDIE model? 2) To what extent is the developed media valid according to a material expert and a media expert? 3) How practical is the developed media according to the classroom teacher and third-grade students? 4) To what extent is the developed media effective in supporting students' mastery of the material, as indicated by the proportion of students who reach the minimum completion criterion?

METHODS

Research Design

This study employed a research and development (R&D) design guided by the ADDIE model, which consists of the analysis, design, development, implementation, and evaluation stages. According to Spatioti et al. (2022), ADDIE is widely used by educational designers and training programmers to develop education and training programs. The product developed in this study was an AR-based learning medium for the science topic of classifying animals by food type. The product was evaluated with a descriptive quantitative approach, and the implementation stage used a single-group design in which students took one evaluation test after learning with the medium.

Figure 1 presents the ADDIE stages that organized the development of the learning medium in this study. The figure is included to show the order of the five stages and how the work moved from one stage to the next. Readers can use it as a map for interpreting the later results, which are reported in the same order. The sequence also shows how the output of one stage became the input of the next stage.

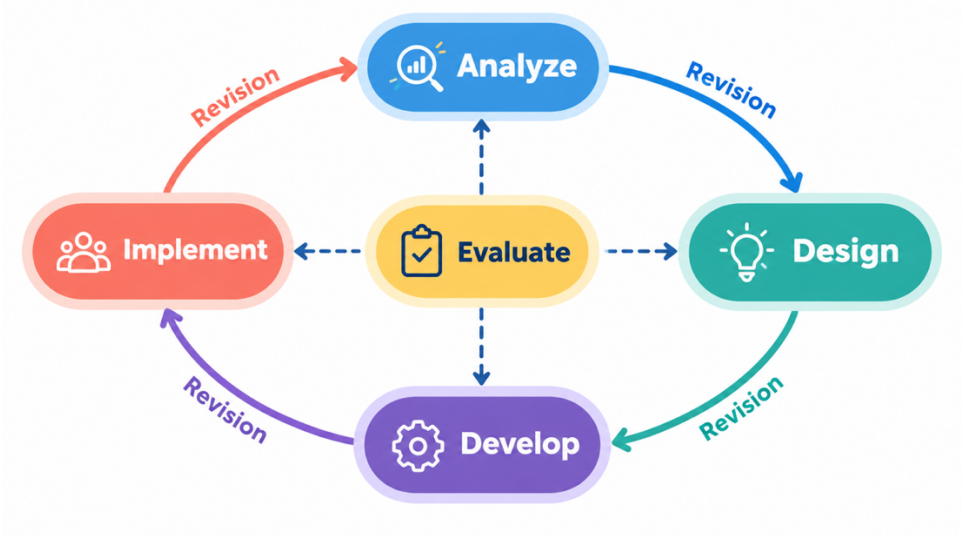


Figure 1. ADDIE model development stages

The figure gives readers a quick overview of the development logic before they encounter the detailed procedures. It reduces the effort needed to follow the link between each stage and the evidence reported in the Results section. For researchers who wish to replicate the study, the figure serves as a concise template of the development sequence. For teachers and developers, it clarifies that the medium was produced through a staged and documented process.

Participants and Setting

The study was conducted in one public elementary school in East Java, Indonesia. The participants were all 16 students of one third-grade class who learned the topic of animal classification by food type. A material expert and a media expert, each holding a master's degree in education, validated the product. The third-grade classroom teacher served as the interview informant and provided the practicality assessment.

Table 1 summarizes the participants and the role of each group in this study. It is included because the study involved three types of respondents who contributed different kinds of evidence. Presenting these roles in one table helps readers see who provided each judgment before the numerical results are reported. This overview also allows readers to judge the size and composition of the sample at a glance.

Table 1. Participants and their roles in the study

Participant group	Number	Role	Data provided
Third-grade students	16	Learners in the implementation trial	Student response questionnaire; evaluation test

Material expert	1	Validator of content suitability	Material validation sheet
Media expert	1	Validator of media appearance and functionality	Media validation sheet
Classroom teacher	1	Interview informant and reviewer of the media	Interview; teacher response questionnaire

The table shows that every judgment in the Results section can be traced to a specific group of respondents. Readers can therefore see that the sample was small and that each expert domain was represented by one validator. This transparency helps readers weigh the strength of the evidence and the limits of generalization. It also helps future researchers decide how to extend the sample in later studies.

Research Procedure

The study followed the five ADDIE stages. At the analysis stage, the researchers interviewed the third-grade teacher to identify learning obstacles and students' needs for learning media. At the design stage, the researchers collected references and learning materials aligned with the Merdeka Curriculum and prepared the initial design, which included animal models for each food category and a quiz feature. These two stages established the problem and the content structure that guided the technical work in the next stages.

At the development stage, the medium was built with the Assemblr Edu application and then submitted to the material expert and the media expert for validation. At the implementation stage, the medium was used in the third-grade class with 16 students on June 23, 2025, and the researcher delivered the lesson. The classroom teacher and the students completed the response questionnaires after the lesson, and the students took the evaluation test. These activities produced the data used to judge validity, practicality, and effectiveness.

At the evaluation stage, the researchers processed the expert validation sheets, the teacher and student questionnaires, and the evaluation test. The percentage of the obtained score from the maximum score was calculated for validity and practicality. The proportion of students who reached the KKM and the class mean were calculated for effectiveness. The results were then interpreted using the criteria presented in Table 3.

Instruments and Data Collection

Table 2 lists the instruments used in this study together with their respondents, purposes, and maximum scores. The table is included because the study relied on several

instruments, and each instrument answers a different research question. Presenting them together helps readers match each result to its source of data. It also helps readers evaluate whether the instruments cover the aspects of validity, practicality, and effectiveness.

Table 2. Instruments, respondents, purposes, and maximum scores

Instrument	Respondent	Purpose	Maximum score
Interview	Classroom teacher	Identify learning obstacles and students' needs for media	Qualitative (not scored)
Material validation sheet	Material expert	Assess suitability of the material to the curriculum and content quality	45
Media validation sheet	Media expert	Assess appearance, functionality, and overall media elements	40
Teacher response questionnaire	Classroom teacher	Assess practicality, ease of use, and suitability for classroom needs	45
Student response questionnaire	16 students	Assess practicality from the students' perspective	480 in total (30 per student)
Evaluation test	16 students	Measure mastery of the material after learning with the medium	Compared with the KKM

The table shows that validity was assessed by two separate validation sheets with different maximum scores. It also shows that practicality was assessed from two perspectives, those of the teacher and of the students. This design gives readers a more balanced view of practicality than a single respondent would provide. The table therefore helps readers understand why the results are reported separately for each respondent group.

Data Analysis

Validity and practicality were calculated as the percentage of the total score obtained from the maximum possible score, namely Percentage (%) = (total score obtained ÷ maximum score) × 100%. Effectiveness was calculated as the percentage of students who reached the KKM from the total number of students, namely Effectiveness (%) = (number of students reaching the KKM ÷ total number of students) × 100%. The class mean score was reported as supporting information for effectiveness. The percentages were interpreted using the categories shown in Table 3.

Table 3 presents the categories used to interpret the percentages for validity, practicality, and effectiveness. It is included to make the interpretation of each result transparent and traceable. Readers can check directly whether a reported percentage

meets the stated category. The table also provides a reference for future studies that wish to apply the same interpretation scheme.

Table 3. Interpretation criteria for validity, practicality, and effectiveness

Aspect	Percentage	Category
Validity	81–100%	Very valid
Validity	61–80%	Valid
Validity	41–60%	Fairly valid
Validity	≤ 40%	Less valid
Practicality	86–100%	Very practical
Practicality	71–85%	Practical
Practicality	56–70%	Fairly practical
Practicality	≤ 55%	Less practical
Effectiveness	≥ 75% of students reach the KKM	Effective
Effectiveness	< 75% of students reach the KKM	Less effective

The criteria allow readers to see which threshold each category requires before they read the results. This helps readers judge whether the labels “very valid,” “practical,” and “effective” were applied consistently. The table also shows that the effectiveness criterion is based on classical completion, which defines what effectiveness means in this study. This clarity protects readers from interpreting the effectiveness result as a measure of learning gain.

RESULTS

The results are presented according to the four research questions. The development process is reported first, followed by validity, practicality, and effectiveness. All percentages were calculated using the formulas described in the Methods section. A summary of the results is provided in Table 5 and in Figures 9 and 10.

Development Process of the AR Learning Media (Research Question 1)

The analysis stage was conducted through an interview with the third-grade teacher to identify learning obstacles in the lesson on classifying animals by food type. The teacher reported that the learning media were limited to posters and that the dominant lecture method made students passive and likely to lose focus. The teacher also explained that students needed media that were more engaging and easier to understand, supported by visuals. Technology-based media such as AR were considered to have the potential to meet these needs.

The design stage began with the collection of references such as books, educational articles, and learning materials aligned with the Merdeka Curriculum on

animal classification by food type. The researchers then compiled the initial design, which consisted of animal models corresponding to the herbivore, carnivore, and omnivore categories. A quiz feature was added to increase student engagement and to give students a way to practice the material. The design was adjusted to the curriculum and to students' learning needs so that learning would feel enjoyable and easier to understand.

The development stage produced the AR learning medium using the Assemblr Edu application. The animal models were arranged into an initial display, a main menu, a user guide, three exploration views for herbivores, carnivores, and omnivores, and a quiz, as shown in Figures 2 to 8. After the medium was completed, it was submitted to a material expert and a media expert for validation. The validation results are reported in the section on validity.

The implementation stage was carried out with 16 third-grade students on June 23, 2025. The researcher acted as the teacher and delivered the lesson on classifying animals by food type using the AR medium. Students viewed three-dimensional visualizations of animals through the device during the lesson. After the lesson, the classroom teacher and the students completed the response questionnaires, and the students took the evaluation test.

The evaluation stage analyzed the expert validation sheets, the teacher and student response questionnaires, and the evaluation test. The analysis aimed to assess the feasibility of the medium and to summarize the development process. The results of this stage form the basis for the conclusions on validity, practicality, and effectiveness. These results are reported in the following sections and are summarized in Table 5.

Table 4 summarizes the activities and outputs of each ADDIE stage. It is included because the development process was described in several paragraphs, and readers benefit from a compact view of what each stage produced. The table lets readers verify that every stage generated a concrete output that supported the next stage. It also gives developers a reference for how a similar medium can be organized.

Table 4. Activities and outputs of each ADDIE stage

Stage	Main activities	Output
Analysis	Interview with the third-grade teacher	Identified obstacles (posters only, dominant lecture method, passive students) and the need for engaging visual media

Design	Collection of references and curriculum-aligned materials; initial design	Animal models for each food category and a quiz feature
Development	Building the medium with Assemblr Edu; expert validation	Initial display, main menu, user guide, three exploration views, and quiz
Implementation	Trial with 16 students on June 23, 2025; response questionnaires and test	Teacher and student responses; evaluation test scores
Evaluation	Analysis of validation, questionnaires, and test	Percentages for validity, practicality, and effectiveness

The table shows that the development process was sequential and that each output had a clear function in the next stage. This helps readers understand that the final medium was a response to the problems identified in the analysis stage. The table also supports the credibility of the study because the process is traceable from the problem to the evidence. For practitioners, it provides a replicable outline for developing similar AR media.

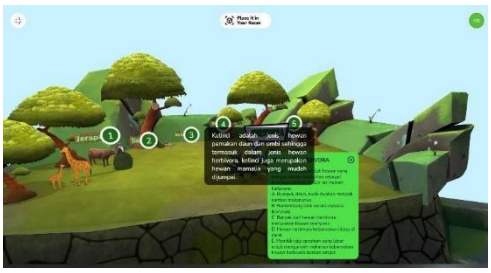
Figures 2 to 4 show the screens of the final learning medium. They are included because readers cannot judge an AR medium from a verbal description alone. The figures present the initial display, main menu, user guide, the three exploration views, and the quiz in the order students experienced them. Together they allow readers to see the content and the interaction flow that were validated and tested.



Figure 2. Initial display of the learning medium



(a) Main menu view



(b) Herbivore category exploration view



(c) Carnivore category exploration view



(d) Omnivore category exploration view

Figure 3. Category exploration view

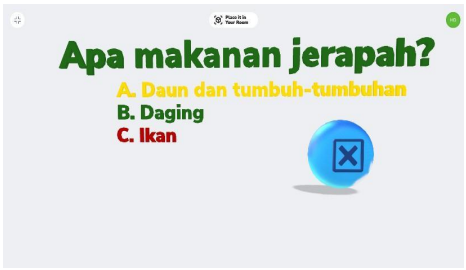


Figure 4. Quiz view

These figures give readers direct visual evidence of the product, which strengthens the link between the development process and the validation results. Readers can see how the three food categories were separated into distinct exploration views and how the quiz closed the learning sequence. The screens also help teachers imagine how the medium would be used in their own classrooms. For developers, the figures serve as a reference for the layout and feature structure that were rated as very valid.

Validity of the Media (Research Question 2)

The material expert gave a total score of 41 out of 45, which equals 91.11% (41 ÷ 45 × 100%) and falls into the very valid category. The media expert gave a total score of 33 out of 40, which equals 82.5% (33 ÷ 40 × 100%) and also falls into the very valid category. Both results meet the very valid threshold shown in Table 3. The material expert noted that some improvements were still needed, and the researchers treated this input as a consideration for refining the medium.

Practicality of the Media (Research Question 3)

The classroom teacher gave a total score of 41 out of 45, which equals 91.11% (41 ÷ 45 × 100%) and falls into the very practical category. The teacher's responses indicated that the medium was easy to use, supported visual and interactive delivery, and helped achieve the learning objectives on animal classification by food type. The student questionnaire produced a total score of 411 out of a maximum of 480, which equals 85.63% (411 ÷ 480

× 100%). This result falls into the practical category, which indicates that students responded positively to the medium.

Effectiveness of the Media (Research Question 4)

In the evaluation test, the class mean score was 83.6. A total of 13 of 16 students reached the KKM, which equals 81.25% (13 ÷ 16 × 100%). This percentage exceeds the 75% classical completion threshold in Table 3, so the medium falls into the effective category. During implementation, some students lacked focus, although most students remained attentive throughout the lesson.

Table 5 summarizes the validity, practicality, and effectiveness results in one place. It is included because the results come from five sources, and readers need a single reference to compare them. The table lets readers see the score obtained, the maximum score, the percentage, and the category side by side. This presentation reduces the need to search through the text for individual numbers.

Table 5. Summary of validity, practicality, and effectiveness results

Aspect	Source of data	Score obtained / maximum	Percentage	Category
Validity	Material expert	41 / 45	91.11%	Very valid
Validity	Media expert	33 / 40	82.50%	Very valid
Practicality	Classroom teacher	41 / 45	91.11%	Very practical
Practicality	Students (n = 16)	411 / 480	85.63%	Practical
Effectiveness	Evaluation test (n = 16)	13 of 16 students reached the KKM; class mean 83.6	81.25%	Effective

The table shows that all aspects met their respective criteria, with the lowest percentage in the effectiveness aspect and the highest in the material validation and teacher response. Readers can quickly identify where the medium performed strongest and where it left more room for improvement. This overview supports the discussion that follows because each interpretation can be checked against a specific row. It also helps practitioners decide whether the medium fits their own requirements.

DISCUSSION

Validity of the Media

Both experts rated the media as very valid, with a higher score from the material expert (91.11%) than from the media expert (82.5%). A plausible explanation is that the content

was organized around three food categories aligned with the curriculum, which supports content suitability (Gnidovec et al., 2020), whereas interface and technical features usually allow more room for refinement (Wen et al., 2023). This interpretation remains tentative because item-level scores and expert comments are needed to confirm it. Ibáñez et al. (2016) examined the effects of scaffolding on learning outcomes and behavior patterns in AR simulation systems. The present media follows an exploration pattern, with category views and a quiz, and it has no scaffolding features such as narration, which offers one direction for improvement. Wen et al. (2023) observed significant gains in self-directed learning and creative thinking in lessons guided by an inquiry-based framework, which is consistent with the emphasis on content and instructional alignment in the validation process. Kyza and Georgiou (2018) described the design and investigation of an AR platform that scaffolds inquiry learning, which indicates that features of this kind can be evaluated empirically alongside learning outcomes. The very valid ratings therefore support the feasibility of the media for classroom trials, while the single validator per domain limits the strength of this evidence. In practice, developers can add audio narration and guided prompts, and future validation should involve more than one expert per domain.

Practicality of the Media

The teacher (91.11%) and the students (85.63%) responded positively to the media. These ratings can be associated with the interactive three-dimensional animal models and the quiz, which gave students visual and active ways to engage with the material, and with reports that primary school students showed satisfaction and low anxiety with AR (Bursali & Yilmaz, 2019) and more positive attitudes toward the course and the technology (Sökmen et al., 2024). Research by Sahin and Yilmaz (2020) found that seventh-grade students who used AR had more positive attitudes toward science and showed no signs of anxiety when using AR applications. Afnan et al. (2021) reported higher motivation among primary school students who learned with AR applications, including an animal application, than among students who learned with videos or textbooks. Khan et al. (2019) found that attention, satisfaction, and confidence increased significantly among undergraduate students after using an AR application, while a decrease in relevance was not significant. The present study reported aggregate scores, so dimension-level differences cannot be identified, and differences in learner age,

instruments, and subject matter should be considered when comparing these patterns. The slightly lower percentage from students than from the teacher may be associated with differences in perspective, because students evaluated their own learning experience, although this explanation cannot be tested with the present data. The researcher delivered the lesson, so the ease of independent use by teachers remains to be examined. Alalwan et al. (2020) identified lack of competency, lack of time, and limited environmental resources as common challenges among primary school science teachers, and Wen et al. (2023) reported that a teacher anticipated time and troubleshooting demands as a limit to adoption by peers. The practical implication is that adoption in schools with limited facilities is likely to benefit from short teacher training and from the availability of devices.

Effectiveness of the Media

A total of 13 of 16 students (81.25%) reached the KKM, and the class mean was 83.6. A possible explanation is that the three-dimensional visualization allowed students to examine animal characteristics for each food category, and the quiz provided immediate practice. Altmeyer et al. (2020) found conceptual knowledge gains only in an AR-supported laboratory condition, which offers a plausible way to interpret how visual exploration supports conceptual understanding, including the classification of animals. The finding is consistent with Sökmen et al. (2024), who reported higher academic achievement among fourth-grade students in the AR group than in the control group. Abdullah et al. (2022) found a favorable effect of AR on primary school students' achievement, and Çetin and Türkan (2022) found significant increases in science achievement and attitudes among third-grade students after AR-based applications. The findings should be interpreted in relation to differences in design, because those studies used comparison groups or pretest-posttest measures, which allow estimation of differences between instructional conditions or of change over time. The present study used a posttest and a completion criterion, so the 81.25% should be read as mastery of the threshold after AR-supported instruction, and learning gain remains untested. Wen et al. (2023) found no statistically significant difference in academic performance when AR was used within an inquiry-based design in primary science, which indicates that the surrounding pedagogy deserves attention, and the present study had no comparison condition to test this point. Three students did not reach the KKM, and some students

lacked focus during the lesson, which may be linked to the cognitive and attentional demands of AR use, since Thees et al. (2022) reported that an AR format did not reduce extraneous load, and Altmeyer et al. (2020) reported cognitive load ratings that were comparable between AR and non-AR conditions. These explanations remain hypotheses because attention and cognitive load were not measured in this study. In practice, teachers can include a short orientation to the device before exploration and use the medium together with other learning activities. Wen et al. (2023) had students work in pairs during AR activities, so small-group use of the medium may be considered in future implementation.

Limitations and Directions for Future Research

Several limitations qualify the findings. The sample consisted of 16 students in one class from one school, and the implementation period was short. The design had no pretest and no comparison group, the researcher delivered the lesson, and one expert validated each domain. The study did not measure retention, attention, or cognitive load, and Bursali and Yilmaz (2019) measured learning permanency on a weekly basis, which supports further evaluation of the medium over longer periods. Future studies can apply quasi-experimental designs with pretests and comparison groups, involve teachers as implementers, include several schools, and measure attention, cognitive load, and retention. Additional features such as audio narration and interactive evaluation can also be developed and tested.

CONCLUSION

This study developed AR-based learning media on animal classification by food type using the ADDIE model and Assemblr Edu. The media was rated very valid by material (91.11%) and media (82.5%) experts, and practical by the teacher (91.11%) and students (85.63%). Of the 16 students, 13 (81.25%) achieved the expected learning outcomes, with a class mean of 83.6. These findings indicate that the media is feasible as a supplementary science learning resource in the studied context. However, learning gains and generalizability remain untested. Teachers who plan to use the media can combine it with guidance and other learning activities, and schools can support adoption through device availability and brief teacher training. Developers can add audio narration and interactive evaluation to strengthen the media. Future research should test the media with pretest-

posttest and comparison-group designs, with teacher-led implementation, and over longer periods. Such studies would show whether the positive results observed here hold across classrooms and over time.

AI Use Statement

The authors used AI tools, if applicable, solely for language editing and proofreading. All authors take full responsibility for the content of this manuscript.

Author Contributions

RIS: contributed to conceptualization, data collection, and manuscript drafting. NLJ: contributed to methodology, data analysis, and manuscript review. LM: contributed to supervision and manuscript revision. All authors approved the final manuscript.

Funding Statement

This research received no specific funding from public, commercial, or nonprofit funding agencies.

Conflict of Interest

The authors declare no conflict of interest.

REFERENCES

Abdullah, N., Baskaran, V. L., Mustafa, Z., Ali, S. R., & Zaini, S. H. (2022). Augmented reality: The effect in students' achievement, satisfaction and interest in science education. International Journal of Learning, Teaching and Educational Research, 21(5). https://doi.org/10.26803/ijlter.21.5.17

Afnan, Muhammad, K., Khan, N., Lee, M.-Y., Imran, A. S., & Sajjad, M. (2021). School of the future: A comprehensive study on the effectiveness of augmented reality as a tool for primary school children's education. Applied Sciences, 11(11), Article 5277. https://doi.org/10.3390/app11115277

Akçayır, M., Akçayır, G., Pektaş, H. M., & Ocak, M. A. (2016). Augmented reality in science laboratories: The effects of augmented reality on university students' laboratory skills and attitudes toward science laboratories. Computers in Human Behavior, 57, 334-342. https://doi.org/10.1016/j.chb.2015.12.054

Alalwan, N., Cheng, L., Al-Samarraie, H., Yousef, R., Alzahrani, A. I., & Sarsam, S. M. (2020). Challenges and prospects of virtual reality and augmented reality utilization among primary school teachers: A developing country perspective. Studies in Educational Evaluation, 66, Article 100876. https://doi.org/10.1016/j.stueduc.2020.100876

Altmeyer, K., Kapp, S., Thees, M., Malone, S., Kuhn, J., & Brünken, R. (2020). The use of augmented reality to foster conceptual knowledge acquisition in STEM laboratory courses: Theoretical background and empirical results. British Journal of Educational Technology, 51(3), 611-628. https://doi.org/10.1111/bjet.12900

Arici, F., & Yilmaz, R. M. (2025). Effects of augmented reality and video-based learning in inquiry-based science education on academic achievement and motivation to learn science. Journal of Computer Assisted Learning, 41(5), Article e70128. https://doi.org/10.1111/jcal.70128

Bursali, H., & Yilmaz, R. M. (2019). Effect of augmented reality applications on secondary school students' reading comprehension and learning permanency. Computers in Human Behavior, 95, 126-135. https://doi.org/10.1016/j.chb.2019.01.035

Cai, S., Liu, C., Wang, T., Liu, E., & Liang, J.-C. (2021). Effects of learning physics using augmented reality on students' self-efficacy and conceptions of learning. British Journal of Educational Technology, 52(1), 235-251. https://doi.org/10.1111/bjet.13020

Çetin, H., & Türkan, A. (2022). The effect of augmented reality based applications on achievement and attitude towards science course in distance education process. Education and Information Technologies, 27(2), 1397-1415. https://doi.org/10.1007/s10639-021-10625-w

Fidan, M., & Tuncel, M. (2019). Integrating augmented reality into problem based learning: The effects on learning achievement and attitude in physics education. Computers & Education, 142, Article 103635. https://doi.org/10.1016/j.compedu.2019.103635

Gnidovec, T., Žemlja, M., Dolenec, A., & Torkar, G. (2020). Using augmented reality and the structure-behavior-function model to teach lower secondary school students about the human circulatory system. Journal of Science Education and Technology, 29(6), 774-784. https://doi.org/10.1007/s10956-020-09850-8

Ibáñez, M.-B., Di-Serio, Á., Villarán-Molina, D., & Delgado-Kloos, C. (2016). Support for augmented reality simulation systems: The effects of scaffolding on learning outcomes and behavior patterns. IEEE Transactions on Learning Technologies, 9(1), 46-56. https://doi.org/10.1109/TLT.2015.2445761

Khan, T., Johnston, K., & Ophoff, J. (2019). The impact of an augmented reality application on learning motivation of students. Advances in Human-Computer Interaction, 2019, Article 7208494. https://doi.org/10.1155/2019/7208494

Kyza, E. A., & Georgiou, Y. (2018). Scaffolding augmented reality inquiry learning: The design and investigation of the TraceReaders location-based, augmented reality platform. Interactive Learning Environments, 27(2), 211-225. https://doi.org/10.1080/10494820.2018.1458039

Sahin, D., & Yilmaz, R. M. (2020). The effect of augmented reality technology on middle school students' achievements and attitudes towards science education. Computers & Education, 144, Article 103710. https://doi.org/10.1016/j.compedu.2019.103710

Sökmen, Y., Sarıkaya, İ., & Nalçacı, A. (2024). The effect of augmented reality technology on primary school students' achievement, attitudes towards the course, attitudes towards technology, and participation in classroom activities. International Journal of Human-Computer Interaction, 40(15), 3936-3951. https://doi.org/10.1080/10447318.2023.2204270

Spatioti, A. G., Kazanidis, I., & Pange, J. (2022). A comparative study of the ADDIE instructional design model in distance education. Information, 13(9), Article 402. https://doi.org/10.3390/info13090402

Thees, M., Altmeyer, K., Kapp, S., Rexigel, E., Beil, F., Klein, P., Malone, S., Brünken, R., & Kuhn, J. (2022). Augmented reality for presenting real-time data during students' laboratory work: Comparing a head-mounted display with a separate display. Frontiers in Psychology, 13, Article 804742. https://doi.org/10.3389/fpsyg.2022.804742

Wen, Y., Wu, L., He, S., Ng, N. H.-E., Teo, B. C., Looi, C. K., & Cai, Y. (2023). Integrating augmented reality into inquiry-based learning approach in primary science classrooms. Educational Technology Research and Development, 71, 1631-1651. https://doi.org/10.1007/s11423-023-10235-y