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PjBL-Based Interactive Puzzle Media for Improving Fifth-Grade IPAS Learning Outcomes on the Human Digestive System

Kusiyo Asih[1] Adi Bandono[2], Susilowati[3]
[123]Universitas PGRI Adi Buana Surabaya, Indonesia

[1]kusiyoasih@gmail.com, [2]adibandono@unipasby.ac.id, [3]susilowati@unipasby.ac.id

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***Correspondence Address:**
kusiyoasih@gmail.com

Abstract:
This study aimed to develop and evaluate Project-Based Learning (PjBL)-based interactive puzzle media to support fifth-grade students' learning outcomes in Natural and Social Sciences (IPAS), particularly on the human digestive system, at SDN Kembangbelor, Pacet, Mojokerto. The study employed a Research and Development (R&D) approach using the ten-stage Borg and Gall model, encompassing needs analysis, product design, expert validation, revision, preliminary trials, field testing, and final revision. The developed media consisted of detachable digestive-system organ pieces, function cards, teacher guidance, and project-based student worksheets designed to facilitate the stages of PjBL. Product feasibility was evaluated by material, media, design, and peer/teacher experts, followed by a one-to-one trial involving 3 students, a small-group trial involving 6 students, and a field trial involving 14 fifth-grade students. Data were collected through observations, interviews, questionnaires, and pretest-posttest learning-outcome tests and were analyzed descriptively and using N-Gain analysis. The validation results indicated high feasibility, with scores of 93% for material, 87% for media, 92% for instructional design, and 100% for peer evaluation, all categorized as very feasible. Student learning outcomes progressively increased across the trials: the mean score increased from 58 to 82 in the one-to-one trial, from 60 to 87 in the small-group trial, and from 66 to 96 in the field trial. In the field trial, the mean N-Gain score was 0.73, categorized as high, while 12 of 14 students (85%) achieved the mastery criterion. Student responses were also positive, with 95% reporting that they enjoyed group- and project-based learning. These findings suggest that the developed media was feasible, practical, and potentially effective for supporting concrete, collaborative, and project-based IPAS learning within the study context.

Introduction (مقدمة)

Natural and Social Sciences (IPAS) learning in elementary school requires experiences that enable students to understand scientific concepts through concrete, contextual, and purposeful activities. Learning media function not merely as aids for delivering content, but as components

of an instructional system that organize stimuli, clarify messages, and help students process information in a more structured manner (Arsyad, 2020; Hidayat & Riyana, 2020; Riyana, 2021). In contemporary learning, this requirement is increasingly important because media are expected to promote activity, collaboration, and student-centered learning rather than merely provide information in a one-way format (Daryanto, 2020; Wibowo & Prasetyo, 2024).

The Merdeka Curriculum for Phase C IPAS directs students to understand human organ systems while developing process skills through observation, investigation, data analysis, reflection, and communication of findings (Kemendikbudristek, 2022; Kemendikbudristek, 2023). This orientation is consistent with the need to assess learning outcomes beyond recall by including understanding, application, analysis, evaluation, and creation (Anderson & Krathwohl, 2019). Therefore, learning designs that provide direct interaction with objects and meaningful tasks are relevant for supporting cognitive achievement as well as student engagement (Astuti & Kurniasih, 2021).

The human digestive system has specific learning characteristics because its organs and physiological processes occur inside the body and cannot be directly observed by students. Digestion involves anatomical relationships, organ functions, mechanical and chemical processes, and their relationship to health (Guyton & Hall, 2021; WHO, 2022). At the elementary-school level, such concepts require concrete and visual representations so that students can construct coherent relationships among organ names, positions, functions, and the sequence of processes (Suryani, 2020; Utami, 2021; Wijayanti & Harimurti, 2023). Concrete media have also been reported to support understanding of difficult science concepts more effectively than instruction that relies too heavily on verbal explanation (Dewi & Santosa, 2021; Rahmawati & Dewi, 2020).

Manipulative media in the form of puzzles provide opportunities for students to learn through visual observation and kinesthetic activity. Pieces that can be removed, attached, arranged, and corrected allow students to explore and receive immediate feedback from the arrangement they produce. These characteristics correspond to the needs of elementary-school students, whose learning remains strongly supported by concrete operational experiences (Catherine, 2022; Putri et al., 2022). Studies reviewed in the thesis indicate that puzzles can support concentration, retention of terms, understanding of structures, motivation, and science learning outcomes (Sari, 2021; Wulandari & Hidayat, 2021; Wulandari & Widodo, 2020; Uyuni & Farida, 2023). More recent developments have also used magnetic puzzles and puzzles accompanied by problem cards to strengthen interaction and student understanding (Harsih & Wahyudi, 2024; Nayaki et al., 2024).

The effectiveness of concrete media is not determined solely by their physical form, but also by the learning scenario that directs students to use the media meaningfully. Project Based Learning (PjBL) positions students in a sequence of essential questions, planning, investigation, collaboration, completion of products or tasks, presentation, and reflection (Krajcik & Shin, 2021; Dewi & Suparna, 2022). PjBL is relevant to science learning because it gives students opportunities to connect concepts with problems, use information, collaborate, and communicate results (Putra & Ningsih, 2020; Mardiani & Setiawan, 2021). Studies cited in the thesis also associate PjBL with improved activity and elementary science learning outcomes (Fajri & Sari, 2021; Putri & Hidayat, 2021; Sari & Utami, 2022).

Integrating media with PjBL creates the possibility of a more complete learning experience because the media provide concrete objects for exploration, while PjBL provides an activity structure through which knowledge is constructed in project work. Project-based media development has been reported to support twenty-first-century skills and active learning (Fitriani & Hidayat, 2022; Hidayat & Sari, 2020). The integration of visual or manipulative media with PjBL has also been associated with retention, critical thinking, and stronger learning outcomes

(Yuliana, 2021; Betu et al., 2024; Putri et al., 2024). In the IPAS context, combining puzzles with PjBL becomes particularly relevant because students can manipulate organ models while engaging in project-based discussion, analysis, and presentation (Sinaga et al., 2025; Meilina, 2024).

Empirical conditions at SDN Kembangbelor demonstrate a clear need for such media. Based on classroom observations and interviews with the classroom teacher in October 2025, instruction on the digestive system was still dominated by oral explanation, textbook reading, and note taking. Available media consisted mainly of textbook pictures or static posters, while collaborative activities had not been optimized. Daily-test data reported in the thesis showed a class mean of 63 against a minimum mastery criterion (KKM) of 70; only 4 of 14 students (28%) met the KKM, while 10 students (72%) did not. The main difficulties involved sequencing the digestive process, explaining organ functions, and understanding relationships among organs.

Student-needs analysis reinforced this picture. Approximately 70% of students stated that the digestive-system topic was fairly difficult because it contained many unfamiliar terms, while 85% stated that they preferred learning with game-based media or group activities. The teacher also emphasized the need for concrete media that students could touch and assemble directly. These needs are consistent with the principle that learning media should be relevant to objectives, simple, attractive, interactive, contextual, safe, and appropriate to learner characteristics (Sanjaya, 2022; Rufii, 2021). From an educational-technology perspective, direct experience through well-organized media can help students build clearer mental representations of abstract subject matter (Degeng, 2020; Widiyanto & Kurniawan, 2020).

Previous studies summarized in the thesis generally follow two lines: the development of puzzles as visual-manipulative tools and the implementation of PjBL as a learning model. Puzzle studies report benefits for learning outcomes, concentration, concept retention, and motivation (Sari, 2021; Wulandari & Hidayat, 2021; Silalahi, 2021), whereas PjBL studies emphasize activity, problem solving, collaboration, and learning outcomes (Putra & Ningsih, 2020; Rahmawati & Sugiyono, 2023). Research integrating manipulative media with PjBL has begun to emerge, but this study specifically positions a digestive-system puzzle as the primary medium for implementing PjBL activities within the Merdeka Curriculum context (Putri et al., 2024).

The research gap lies in the limited availability of concrete media deliberately designed to facilitate the stages of PjBL, particularly in elementary schools where the use of digital technology is still limited. The product developed in this study does not function only as a visualization of organ structures; it is integrated with function cards, a student worksheet (LKPD), a teacher guide, and a project sequence through which students observe, assemble, identify functions, analyze relationships among organs, present results, and reflect. This orientation is consistent with media-development principles requiring content validity, design quality, practicality, and evidence of effectiveness through user evaluation (Rahmatullah & Fauziah, 2020; Prasetyo & Lestari, 2024).

Accordingly, the novelty of this study lies in developing PjBL-based interactive puzzle media specifically for the human digestive system in fifth-grade students and evaluating the product through expert validation, one-to-one trials, small-group trials, and a field trial. The study aims to describe the product-development process, assess its feasibility and practicality, and analyze its effectiveness in improving the IPAS learning outcomes of fifth-grade students at SDN Kembangbelor.

Method (منهج)

This study employed a Research and Development (R&D) approach using the procedural Borg and Gall model as applied in the thesis. R&D was selected because the research aimed to produce a learning product that could be developed, validated, revised, tested, and refined on

the basis of evidence from its use. This framework is consistent with development research in which product evaluation is part of an iterative refinement cycle (Sugiyono, 2022; Prasetyo & Lestari, 2024).

The Borg and Gall model was implemented through ten stages: (1) identifying potentials and problems, (2) collecting information, (3) designing the product, (4) validating the design, (5) revising the design, (6) conducting product trials, (7) revising the product, (8) conducting usage trials, (9) carrying out further product revision, and (10) producing the product on a broader scale. In this study, the stages were used to develop an interactive human-digestive-system puzzle integrated with the PjBL syntax. The development flow used in the study is shown in Figure 1.

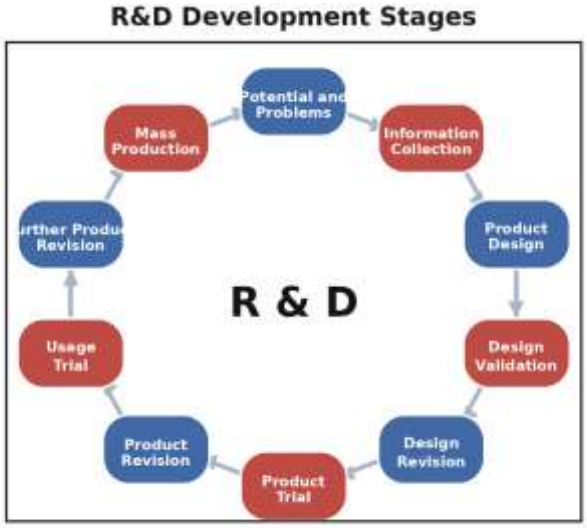

Figure 1. Borg and Gall R&D development model used in the study

The study was conducted at SDN Kembangbelor, Pacet District, Mojokerto Regency. The field-trial participants were all 14 fifth-grade students. Product evaluation was conducted progressively: the one-to-one trial involved 3 students, the small-group trial involved 6 students, and the field trial involved 14 students. Product validation involved a material expert, a media expert, a design expert, and a peer/classroom teacher. This staged procedure was used to identify initial deficiencies, examine practicality, and test product use under increasingly realistic classroom conditions.

Table 1. Trial Stages and Research Participants

Stage	Participants	Main Purpose
Expert validation	Material, media, and design experts; peer/teacher	Assess content, media, design, and evaluation feasibility
One-to-one trial	3 students	Identify initial usability and readability problems
Small-group trial	6 students	Assess practicality, initial responses, and technical problems
Field trial	14 fifth-grade students	Assess effectiveness, learning outcomes, responses, and PjBL implementation

The initial product consisted of one set of human-digestive-system puzzle media containing six detachable organ pieces, six organ-function cards, one teacher guidebook, and one project-based student worksheet (LKPD). The media were designed as a tangible and manipulative product of approximately A3 size and were intended for group use. The product's manipulative and visual characteristics were selected to support direct learning experiences, as emphasized in

studies of concrete instructional media for elementary-school learners (Catherine, 2022; Putri et al., 2022).

The PjBL syntax applied in the study included determining an essential question, planning the project, scheduling activities, implementing the project through investigation-construction-collaboration, testing and evaluating project results, and reflection. During implementation, students observed the organ pieces, arranged the sequence of digestive organs, identified organ names and functions, analyzed relationships among organs, solved problems through group discussion, and recorded the results in the LKPD. This activity pattern reflects the characteristics of PjBL in which investigation and collaboration contribute to the construction of understanding (Krajcik & Shin, 2021; Dewi & Suparna, 2022).

The study used qualitative and quantitative data. Qualitative data were obtained from observations, interviews, validator comments, and teacher and student responses. Quantitative data consisted of validation scores, response-questionnaire scores, and pretest-posttest learning-outcome scores. Validation instruments used a 1-5 Likert scale and covered content, presentation, visual/illustration quality, design, and evaluation. The assessment instruments were prepared according to principles of systematic program evaluation and assessment (Arikunto & Jabar, 2020; Ananda & Rafida, 2020).

Expert-validation data were analyzed using percentages and the feasibility categories specified in the thesis. Learning outcomes were analyzed by comparing pretest and posttest scores and by calculating N-Gain using g = (posttest - pretest)/(maximum score - pretest). The criteria were g > 0.70 = high; 0.30 < g <= 0.70 = medium; and g <= 0.30 = low. The use of N-Gain to examine improvement in learning achievement is also employed in evaluations of science learning (Nurhayati & Rahman, 2021). Qualitative data were analyzed descriptively through data reduction, data display, and drawing conclusions from field findings.

In addition to cognitive outcomes, the study recorded student activity, participation, cooperation, and responses during media use. These aspects are important in project-based learning because the learning process is evaluated not only from the final product but also from students' engagement in activities and group performance (Huda et al., 2020; Pratiwi & Suryadi, 2022; Rahmawati & Fitriani, 2024). However, consistent with the thesis limitations, the main effectiveness analysis in this article remains focused on the reported learning-outcome and N-Gain data, while affective and psychomotor findings are presented as observational and user-response evidence.

Result (نتائج)

Needs Analysis and Initial Conditions

The needs analysis indicated that learning problems occurred in the areas of media, instructional process, and learning outcomes. Instruction still centered on teacher explanations and textbooks, while concrete media that allowed students to manipulate objects were not available. The teacher reported that students frequently had difficulty sequencing the digestive process and distinguishing the functions of the small and large intestines. This condition is consistent with the characteristics of organ-system content, which requires visual and manipulative support so that structure-function relationships can be understood more concretely (Suryani, 2020; Utami, 2021; Wijayanti & Harimurti, 2023).

Quantitatively, the initial data showed an average daily-test score of 63, below the KKM of 70. Four of 14 students (28%) met the KKM, while 10 students (72%) had not yet achieved mastery. The needs questionnaire also showed that approximately 70% of students considered the digestive-system topic fairly difficult, whereas 85% preferred learning through game-based media or group activities. Table 2 summarizes these initial conditions. These findings became the basis for developing media emphasizing visualization, manipulation, and collaboration.

Table 2. Summary of Initial Conditions and Learning Needs

Indicator	Finding
Average daily-test score	63
Minimum mastery criterion (KKM)	70
Initial mastery	4/14 students (28%) achieved mastery; 10/14 (72%) had not
Student difficulty	Approximately 70% considered the topic fairly difficult because of unfamiliar terms
Learning preference	85% preferred game-based media or group activities
Teacher findings	Difficulty sequencing digestion and distinguishing organ functions; media remained static; collaborative activity was limited

Product Design and PjBL Integration

Based on these needs, the product was developed as an interactive digestive-system puzzle containing six detachable main organs, function cards, a teacher guidebook, and a project-based LKPD. The media were not positioned as a stand-alone game but as a tool for implementing PjBL activities. At the essential-question stage, students were directed to understand a problem related to the digestive process; during the project stage, they arranged the organs, connected structure and function, completed the LKPD, presented their work, and reflected on the learning process.

The design was grounded in the principles of concrete experience and knowledge construction. Degeng (2020) emphasizes the importance of systematically organized direct experience, whereas Rufii (2021) positions manipulative media as tools that help students explore and validate their understanding. Its compatibility with the concrete operational stage is visible in activities that require touching, arranging, comparing, and correcting puzzle configurations. Thus, the product combines visual representation with direct action rather than requiring students only to read information on cards or in books.

Figure 2 shows the product during the validation process. The documentation illustrates the physical puzzle that served as the central object of the learning activities. The use of physical media was relevant to the school context described in the thesis, where digital technology use was limited; therefore, the product was designed to be practical, economical, and independent of complex technological devices.

Figure 2. Interactive puzzle media during the product-validation process

Expert Validation and Product Revision

Validation was conducted before the product was used more broadly. Detailed validation tables in the thesis reported feasibility scores of 93% from the material expert, 87% from the media expert, 92% from the design expert, and 100% from the peer/teacher evaluation; all were categorized as very feasible. The material expert evaluated content relevance, conceptual accuracy, clarity of visual presentation, and the suitability of the evaluation instrument. The media expert evaluated interactive-media presentation, media content, and illustrations, whereas the design expert evaluated the cover, content feasibility, presentation, illustrations, and evaluation instrument. The results are summarized in Table 3.

The validation scores indicate that the product met content and presentation feasibility requirements before classroom trials. Pedagogically, this result is consistent with the principle that appropriate learning media should meet requirements for content accuracy, readability, visual suitability, and alignment with instructional objectives (Rahmatullah & Fauziah, 2020; Rufii, 2021). Media-development literature cited in the thesis also stresses the importance of validation and revision before field implementation so that a product is not merely attractive but also conceptually and instructionally sound (Prasetyo & Lestari, 2024; Widiyanto & Kurniawan, 2020).

Validator feedback was used as the basis for revision. Improvements included adding an explanation of peristaltic movement, adding explanations of mechanical and chemical digestion, enlarging the font size, increasing color contrast, and clarifying the sequence of organs. During the small-group trial, the LKPD instructions were made more detailed, the text on the function cards was enlarged, and directional arrows were added to indicate the digestive pathway. These revisions demonstrate that the R&D process did not stop at feasibility scoring but used feedback to improve product functionality. Table 7 summarizes the major revisions reported in the thesis.

Table 3. Product Feasibility Validation Results

Validator	Score/Percentage	Category
Material expert	79/85 (93%)	Very feasible
Media expert	52/60 (87%)	Very feasible
Design expert	92/100 (92%)	Very feasible
Peer/teacher	70/70 (100%)	Very feasible

Staged Trials and Practicality

The staged trials showed improvements in learning outcomes while also providing information about ease of use. In the one-to-one trial with 3 students, the mean pretest score of 58 increased to 82 on the posttest, an increase of 24 points. Findings at this stage indicated that the media could generally be used by students, but minor problems remained in the clarity of instructions and text readability; these findings were then used to revise the product.

In the small-group trial with 6 students, the mean pretest score increased from 60 to 87 on the posttest, a gain of 27 points. Observations showed that students were enthusiastic and active while arranging the puzzle, most participated in group discussion, and 5 of 6 students (83%) were able to arrange the sequence of organs correctly without assistance. Students also began to explain digestive-organ functions in their own words. This pattern suggests that after the instructions and visual presentation were revised, the media became easier to use in group activities.

The field trial involved all 14 fifth-grade students. The thesis reported a mean pretest score of 66 and a mean posttest score of 96, representing a reported mean increase of 30 points. Mastery data in the field-trial table showed that 12 of 14 students (85%) achieved mastery, while 2 students

(15%) had not. Results from the one-to-one, small-group, and field trials are summarized in Table 4. Documentation of the field-trial implementation is presented in Figure 3.

The consistent improvement across the three trial stages supports the function of the media as a concrete learning resource. Studies cited in the thesis similarly report that manipulative media can improve conceptual understanding and science learning outcomes in elementary-school students (Handayani & Mulyani, 2023; Lestari & Kurniawan, 2023; Mulyani et al., 2023). These results are also consistent with reports on the use of puzzles for learning outcomes, concentration, and concept retention (Sari, 2021; Wulandari & Hidayat, 2021; Wulandari & Widodo, 2020).

Table 4. Summary of Staged Trial Results

Stage	N	Mean Pretest	Mean Posttest	Increase	Additional Information
One-to-one	3	58	82	24 points	Instructions and readability were revised
Small group	6	60	87	27 points	5/6 students (83%) arranged the organ sequence without assistance
Field trial	14	66	96	30 points	12/14 students (85%) achieved mastery; N-Gain 0.73 (high)

Figure 3. Field-trial implementation in fifth-grade IPAS learning

Learning-Outcome Improvement and N-Gain

N-Gain analysis was used to examine the relative improvement from initial scores toward the maximum score. The reported average N-Gain was 0.73, categorized as high. Individual N-Gain values ranged from 0.22 to 1.00. Most values were in the high category, several were in the medium category, and one student was in the low category. The individual values reported in the thesis are presented in Table 5.

This variation is important because group-level effectiveness does not imply that every student improved to the same extent. High N-Gain values for most participants indicate that the media worked well for the majority of students, while the low score for one student points to the need to consider differences in prior ability and individualized learning support. Within an

assessment framework, examining individual gains helps prevent interpretations that depend only on group means (Nurhayati & Rahman, 2021; Brookhart, 2020).

Conceptually, the improvement in learning outcomes can be explained by the combination of media characteristics and the learning model. The puzzle transforms abstract concepts into structures that can be observed and manipulated, while PjBL directs students to use this information in investigation, discussion, task completion, presentation, and reflection. The finding is consistent with studies linking concrete media to conceptual understanding (Dewi & Santosa, 2021; Rahmawati & Dewi, 2020) and PjBL to science activity and achievement (Fajri & Sari, 2021; Putri & Hidayat, 2021; Rahmawati & Sugiyono, 2023).

Table 5. Individual N-Gain Distribution in the Field Trial

Respondent	N-Gain	Category
S1	0.71	High
S2	0.22	Low
S3	0.83	High
S4	0.80	High
S5	1.00	High
S6	0.83	High
S7	1.00	High
S8	0.80	High
S9	0.60	Medium
S10	0.71	High
S11	0.42	Medium
S12	0.67	Medium
S13	0.80	High
S14	0.90	High
Mean	0.73	High

Student Responses and Classroom Dynamics

Student responses showed positive acceptance of both the media and the learning scenario. Positive responses were 92% for learning being more enjoyable, 93% for the media being attractive and not boring, 86% for helping students understand the material, and 95% for enjoying group- or project-based learning. These four indicators are presented in Table 6.

The response data show that the product's benefits were not limited to changes in cognitive scores. Classroom observations showed that students asked more questions and participated more actively in discussion, all groups were involved in assembling the puzzle, students appeared more confident when presenting project results, and previously passive students began to participate in group discussions. Students also divided roles independently, including arranging the puzzle, reading the function cards, and recording results. The discussions became two-way and collaborative.

These findings are consistent with studies that identify media interactivity as a factor that can strengthen student motivation and engagement (Silalahi, 2021; Catherine, 2022). PjBL also provides a structure for cooperation and communication because students carry out group tasks with clear goals and products (Krajcik & Shin, 2021; Putra & Ningsih, 2020). Other studies cited in the thesis indicate that project-based learning can strengthen motivation, retention, and critical-thinking skills (Mardiani & Setiawan, 2021; Sari & Utami, 2022; Betu et al., 2024).

Such engagement is important in IPAS learning because science-process skills require students to observe, question, analyze, and communicate results. The puzzle provides an object that can be observed and reconstructed, while the LKPD and presentations provide space for students to articulate concepts. Science-process skills in IPAS require activities that allow students to process information and communicate their understanding (Khodijah & Aulia, 2023; Larson & Miller, 2021).

Table 6. Student Responses to the Media and Learning Process

Aspect	Positive Response

Learning was more enjoyable	92%
The media were attractive and not boring	93%
The media helped students understand the material	86%
Students enjoyed group- or project-based learning	95%

Product Revision as Formative Evaluation

Product revision was conducted progressively on the basis of expert validation and user experience. This stage was important because product feasibility was not determined by validation scores alone; readability, information sequence, instructions, and physical durability also required adjustment after use. Table 7 summarizes the main improvements reported in the thesis.

Table 7. Summary of Product Revisions Based on Validation and Trials

Component	Finding/Before Revision	Improvement
Esophageal function	The explanation was still brief	An explanation of peristaltic movement was added
Digestive process	The process sequence was incomplete	Mechanical and chemical digestion were added
Font size	Some text was difficult for students to read	The font was enlarged for elementary-school students
Background color	Contrast was not optimal	The background was revised for more comfortable viewing
Organ sequence	The puzzle arrangement was not systematic	The organ sequence was clarified according to the digestive pathway
LKPD instructions	The work steps were not sufficiently detailed	Clearer and more systematic work steps were added
Function cards	The text was difficult to see	The font size was enlarged
Puzzle assembly	Students were unsure where to begin	Directional arrows were added to show the digestive pathway

Discussion (مناقشة)

Overall, the findings demonstrate a complementary relationship between the physical form of the media and the instructional design. The product was not attractive merely because it was a puzzle; it also had an instructional function. Each organ piece, function card, and project task was positioned to help students construct the sequence of the digestive process and structure-function relationships. This principle is consistent with the view that instructional media should be designed around learning objectives and processes rather than aesthetic considerations alone (Arsyad, 2020; Degeng, 2020; Hidayat & Riyana, 2020).

In terms of content, the digestive system is vulnerable to misconceptions because students may misunderstand organ functions, process sequences, and the distinction between mechanical and chemical digestion. Media that allow students to arrange organs sequentially and read their functions directly can provide a more structured representation. This need is consistent with studies on visual models and organ-system media in elementary science learning (Suryani, 2020; Utami, 2021; Rahmawati & Dewi, 2020). Human-organ puzzles have also been reported to support concept retention, while more recent puzzle developments extend their function through interactivity and contextual problems (Wulandari & Widodo, 2020; Harsih & Wahyudi, 2024; Nayaki et al., 2024).

At the model level, PjBL transforms media use from an individual manipulative activity into a social and investigative process. Students did not merely place puzzle pieces; they discussed, divided roles, interpreted organ functions, completed the LKPD, and presented results. This finding strengthens previous research showing that PjBL can improve activity, problem-solving ability, and learning outcomes (Hidayat & Sari, 2020; Fajri & Sari, 2021; Putri & Hidayat, 2021). Integrating manipulative media with PjBL has also been reported to produce stronger achievement gains than using media in isolation (Putri et al., 2024; Sinaga et al., 2025).

High validation results across material, media, design, and peer evaluation indicate that the product was considered appropriate in both content and operation before the field trial. The

revision process also illustrates the role of formative evaluation: material-expert feedback improved conceptual accuracy, while media-expert and user feedback improved readability, contrast, sequence, and instructions. This principle is consistent with media-development research emphasizing that validity and practicality should be built through repeated evaluation and revision (Rahmatullah & Fauziah, 2020; Prasetyo & Lestari, 2024).

The field-trial result, which reported a 30-point increase in the mean score and an N-Gain of 0.73 in the high category, provides quantitative evidence of product effectiveness within the studied group. This finding is consistent with research indicating that manipulative media can strengthen conceptual understanding (Handayani & Mulyani, 2023; Lestari & Kurniawan, 2023) and with PjBL studies reporting improvements in learning outcomes and engagement (Mardiani & Setiawan, 2021; Sari & Utami, 2022). The PjBL-based interactive multimedia and STEAM-PjBL studies cited in the thesis also show a similar direction for activity and scientific literacy in the IPAS context (Meilina, 2024; Nursalim, 2024).

Nevertheless, the findings must be interpreted within the limits of the research context. The field-trial participants consisted of only 14 students from one school, the research period was limited, and effectiveness was examined with a single-group design without a comparison group. The thesis also states that learning-outcome measurement focused mainly on the cognitive domain, whereas affective and psychomotor domains were not measured in depth using dedicated instruments. Therefore, observations and responses concerning motivation, activity, and collaboration should be interpreted as descriptive evidence complementing the learning-outcome data rather than as separate experimental measures.

A practical implication of the study is that schools with limited digital technology can still develop interactive learning experiences through pedagogically designed physical media. The puzzle can be reused, is easy to understand, and enables students to work collaboratively. The recommendations already contained in the thesis include expanding the sample and number of schools, using a control group, developing digital or hybrid versions, developing more comprehensive affective and psychomotor instruments, testing long-term retention, and adapting the media to other IPAS topics.

Conclusion (خاتمة)

The study successfully developed PjBL-based interactive puzzle media for fifth-grade IPAS learning on the human digestive system at SDN Kembangbelor using the Borg and Gall R&D approach. The product was developed through needs analysis, design, validation, revision, and staged trials. Detailed validation results in the thesis showed feasibility scores of 93% from the material expert, 87% from the media expert, 92% from the design expert, and 100% from the peer/teacher evaluation, all in the very feasible category.

The trials showed improvement in learning outcomes at every stage: the mean increased from 58 to 82 in the one-to-one trial, from 60 to 87 in the small-group trial, and from 66 to 96 in the field trial. The mean field-trial N-Gain was 0.73, categorized as high, while the field-trial table reported that 12 of 14 students (85%) achieved mastery. Student responses were also positive: 92% for more enjoyable learning, 93% for attractive and non-boring media, 86% for helping students understand the material, and 95% for enjoyment of group- or project-based learning.

These findings indicate that the developed media were feasible, practical, and effective within the context of this study and supported concrete and collaborative learning. Generalization should remain cautious because the study involved one school, a small number of participants, a limited research period, and a single-group design. Consistent with the recommendations in the thesis, subsequent development may involve larger and more diverse samples, a comparison group, long-term retention testing, digital or hybrid versions, and adaptation of the media to other IPAS topics.

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