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Development of Learning Media Pop-Up Book of Digestive System Material in Human Grade V Elementary School Based on STEAM

Moh. Irma Sukarelawan[1]*, Panji Hidayat[2], Raden Oktova[1], Rifdah Gika Nurzannah[2], Sabrina Amelia Putri[2], Ilham Mustaqim[2], Siti Wulandari[2], and Wiranda[1]

[1]Physics Education Study Program, Universitas Ahmad Dahlan, Yogyakarta, Indonesia
[2]Primary Education Study Program, Universitas Ahmad Dahlan, Yogyakarta, Indonesia
*irma.sukarelawan@pfis.uad.ac.id

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Abstract

Learning in elementary schools faces challenges in increasing student engagement with materials that are considered less interesting, especially in understanding abstract scientific concepts such as the human digestive system. Therefore, this study aims to develop STEAM-based pop-up book learning media to facilitate fifth-grade elementary school students' understanding of the human digestive system. This research is included in the 4D Research and Development model. Two experts were involved as media experts, and 16 students were potential users. The quality of pop-up book media is assessed based on 15 items spread over 5 aspects that refer to STEAM elements. Each item uses a 6-point Likert rating scale. The development results produced learning media such as pop-up books based on the STEAM approach in learning human digestive system material for grade V elementary school students. Based on the expert agreement index of the Gregory model used, the pop-up book developed has very good feasibility, an index of 1.00. This product successfully combines three-dimensional (3D) visual elements and is considered feasible by media experts. This pop-up book media can be an innovative alternative for learning in elementary schools that can increase student engagement and facilitate understanding of complex scientific concepts.

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INTRODUCTION

One of the phenomena underlying the development of learning media is the increasing number of media options that can support the teaching and learning process (Im et al., 2025; Kurniawan et al., 2025). Among the various types of media available, visual media, including Pop-up Books, is one of the increasingly popular choices due to its ability to provide a more interactive and multisensory experience for students (Kiliç, 2021; Saputra et al., 2025). Pop-up books, which combine elements of traditional books with three-dimensional shapes that can "open" or "appear" when the pages are turned, are an interesting innovation for supporting the understanding of abstract concepts in science lessons.

In Indonesia's education context, many primary-level students often face difficulties in visualizing abstract scientific concepts (Akram et al., 2022; Zhong, 2023), such as the human

digestive system. This is due to the lack of media that can depict in a real and detailed way how the digestive process takes place in the human body. Most existing textbooks still use textual approaches and two-dimensional images that are sometimes less able to arouse students' imagination.

Pop-up books as learning media provide a visual and kinesthetic experience that is very different from ordinary textbooks (Kiliç, 2021; Rusanti et al., 2023). With elements that lift and move, pop-up books rely on static text and images, creating a new dimension in the learning process that invites students' curiosity. For example, in the topic of the human digestive system, pop-up books can depict the organs of the human body in three dimensions, such as the stomach, small intestine, and liver, which can be seen more clearly in a more interesting perspective and facilitate students' understanding of the functions and relationships between these organs.

Another phenomenon that encourages the development of pop-up book media is the tendency of today's children to use digital devices in their daily activities. These digital native children are more accustomed to using technology and media that are engaging and interactive (Matang et al., 2023; Ramírez, 2024). Therefore, more visual and fun learning methods will be more effective in attracting their attention. Although not a digital technology, pop-up books offer interactivity and a different experience through physical elements that students can feel directly. This creates a stronger emotional connection between students and the subject matter.

In addition, constructivism-based learning approaches are increasingly developing in basic education (Tanjung et al., 2023), emphasizing the importance of direct experience for students to build their understanding. Pop-up books can support this approach by allowing students to interact more actively with the subject matter (Kurniawan et al., 2023), rather than passively receiving information. By opening the pages and seeing how the three-dimensional images or illustrations appear, students can better understand the complex process of the digestive system in a more fun and easy-to-understand way.

These phenomena indicate a deep need for innovation in learning media, which can encourage student interest (Aini et al., 2023), improve their understanding of the subject matter (Damayanti et al., 2024), and provide a more interesting learning experience (Halimah et al., 2024). Therefore, developing pop-up book-based learning media for human digestive system material in grade V elementary school is very relevant and necessary to meet education needs that are more effective, creative, and fun for students.

Learning that involves visual and interactive aspects is very important to increase student interest and understanding (Philominraj et al., 2017; Sukmawati et al., 2024). Children at elementary school tend to understand information more easily when it is delivered in a way that combines visual and kinesthetic elements. The human digestive system is material that requires an understanding of the functions and relationships between different organs. Static learning media, such as textbooks, are challenging to use to explain the complex relationships between materials in a way that is easy to understand. Therefore, developing pop-up book media for digestive system material can effectively facilitate more enjoyable and in-depth learning.

Previous studies have shown that pop-up book media effectively improve student learning outcomes in various subjects and levels of basic education. This media is proven to be visually appealing, interactive, and able to facilitate students' understanding of complex material. However, the media development approaches used are mostly conventional or based on a single pedagogical approach, such as contextual, problem-based, or contextual teaching and learning (Andini & Wati, 2024; Anindita & Wardani, 2025; Nurusiah et al., 2024).

For example, Safitri's (2025) research developed Canva-based pop-up book media for grade IV IPAS subjects. It significantly increased learning outcomes but has not integrated cross-disciplinary approaches such as STEAM. Similarly, the effect of pop-up book media on science learning outcomes and student literacy skills has been widely studied (Aprilia et al., 2025; Loliyana et al., 2022; Muna et al., 2024; Nazhirah et al., 2024; Resta & Kodri, 2023), but no research explicitly develops pop-up books in the integrative framework of Science, Technology, Engineering, Arts, and Mathematics (STEAM). Even in media development with innovative approaches such as crossword puzzles (Muna et al., 2024) or based on local wisdom (Nabila et al., 2021), no systematic integration of the five elements in STEAM was found.

Furthermore, although essential in the fifth-grade science curriculum, human digestive system material has never specifically been the focus of pop-up book media development in previous studies. Some studies have worked on similar themes, such as ecosystems or the water cycle (Hikmah et al., 2022; Muna et al., 2024; Nazhirah et al., 2024), but the digestive system has not received attention as material developed through interactive visual media.

Therefore, this study aims to develop pop-up book-based learning media that can facilitate the understanding of grade V elementary school students of the human digestive system material. This research is expected to significantly contribute to the world of education, especially in developing more interactive and creative learning media. By integrating pop-up book media in learning, it is expected that students can be more interested and actively involved in the learning process. In addition, this research can also be a reference for developing other learning media that are more innovative and by student learning needs. On the other hand, the results of this study can open opportunities for further research related to the use of creative media in science learning at the elementary level.

METHODS

This research belongs to the type of Research and Development (R&D). The development model refers to the 4D model (Define, Design, Development, Disseminate) (Yusuf et al., 2024). This research was limited to the development stage, as depicted in Figure 1. The research and development process was carried out over about five months.

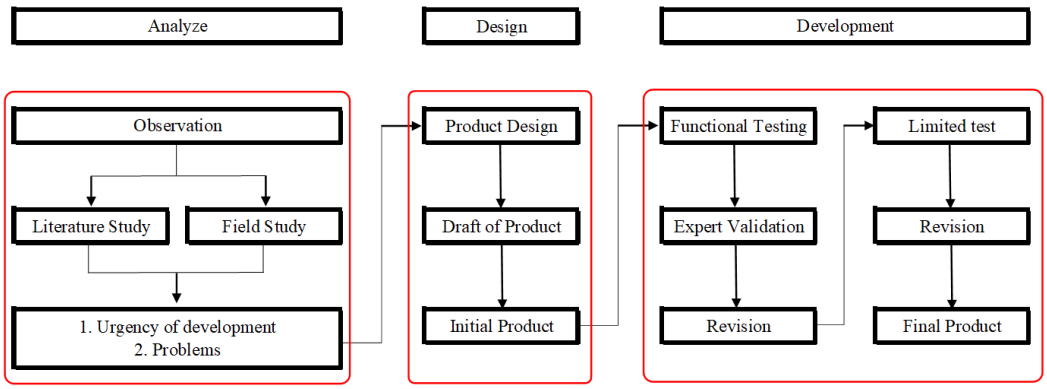


Figure 1 Research procedure

This study involved two experts who assessed the product from the media aspect and 16 students who acted as prospective users of teaching materials. The instrument used to assess the product from a media perspective by experts and prospective users consisted of 15 items divided into five aspects of assessment, namely, science (3 items), technology (3 items), engineering (3 items), arts (3 items), and mathematics (3 items). This instrument's rating

scale is a Likert scale with 6 points, ranging from 1 (strongly disagree) to 6 (strongly agree). The reliability of this instrument is 0.95.

The data analysis technique used in this study consisted of two main approaches. First, for the assessment by media experts, the Gregory agreement technique was used (Retnawati, 2016), which focuses on the consensus between experts in assessing the quality and suitability of the product based on media aspects. This technique allows researchers to identify the extent to which experts agree on the product's characteristics being assessed to obtain a more objective and valid assessment.

Second, for the assessment conducted by prospective users, the Logit Value of Item (LVI) approach was used in combination with the Wright map in Rasch modelling (Ramdhan et al., 2022). The LVI technique analyzes respondent data in the context of the Rasch model, which allows one to assess the developed product's strengths and weaknesses.

Combining these two approaches allows for a more comprehensive and accurate data analysis. It ensures that the research results can describe product quality more objectively and validly from the perspective of experts and potential users.

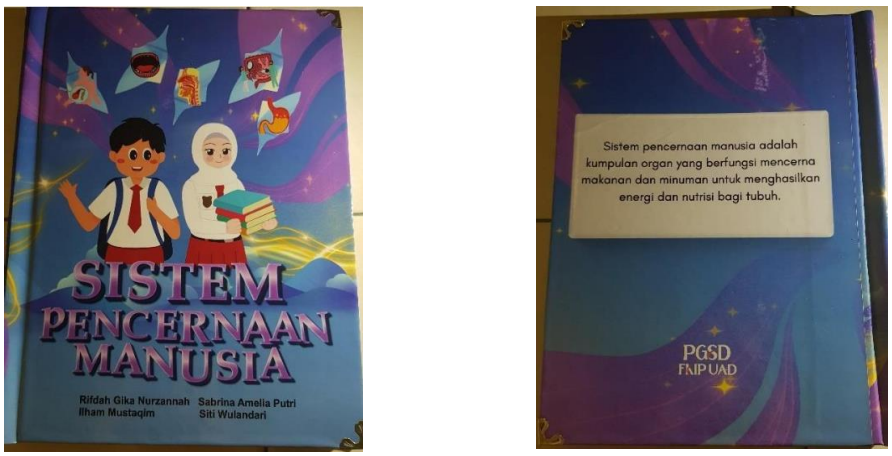
RESULTS AND DISCUSSION

Product

The Human Digestive System Pop-up Book is a book that uses a three-dimensional (3D) mechanism, where certain parts of the page will lift or move when the page is opened, forming a more vivid image or scene. With the help of this 3D visual element, concepts related to the organs in the digestive system can be visualized more concretely. This helps students to understand abstract material in a more tangible way through text and three-dimensional images (Andreansyah & Sari, 2024; Nurazizah & Nuryami, 2024). This media design also aims to make the material delivery process more interesting, increasing student interest in learning and facilitating understanding of the material presented.

Media Pop-up Book: The human digestive system consists of several main parts: a cover, illustrations of the main organs, an illustration of the tongue, an illustration of the main digestive system in humans, and information about the proportion of food in a healthy diet.

The cover image of the Human Digestive System Pop-up book can be seen in Figure 2.



(a) Front cover (b) Back Cover

Figure 2 Pop-up book cover
Source: Authors

The book's front cover (Figure 2a) features bright and dynamic illustrations depicting the educational theme of the human digestive system. Two characters, a student and a female

student, enthusiastically hold the book amidst a graphic background of brightly colored digestive organs, creating an attractive and friendly atmosphere. This design combines a calming blue with cheerful elements, making it suitable for students and those who want to learn about the digestive system. On the back of the cover (Figure 2b) is an explanation of the human digestive system. Overall, this design attracts attention and creates an accessible impression, arouses curiosity, and makes it easy for students to associate the illustrations with the material to be learned. An anatomical illustration of the major organs in the digestive system is also shown in Figure 3.

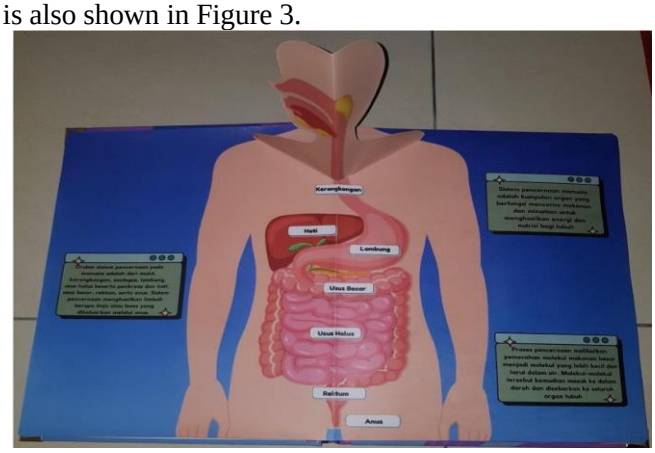


Figure 3 An anatomical illustration of the major organs in the digestive system

Figure 3 shows an anatomical illustration of the main organs in the digestive system, starting from the esophagus, stomach, small intestine, large intestine, rectum, and anus. Each organ is clearly labeled and easy to read, making it easier for students to understand the position and function of each organ. Around the illustrations are text boxes that explain the digestive process in detail, including the specific functions of each organ and the stages in food digestion. For example, the digestive process begins with the chewing of food in the mouth, followed by the absorption of nutrients through the small intestine, and finally the process of removing food waste through the anus. With an engaging and informative design, this section aims to facilitate students' understanding of how the body digests food and invites students to explore the digestive system in a fun and easy-to-understand way. This is in line with what was said by Tisza (2021) that enjoyable learning can influence students' positive attitude towards learning, which leads to improved academic performance (Silvia & Rigianti, 2023).

This illustration is designed to provide a clear visual picture of the anatomy and function of the organs in the human digestive system. The clear labeling of each organ allows students to easily understand the position and function of each part in the body. Adding text boxes that explain the digestive process in detail provides additional in-depth information, helping students understand the anatomical structure and physiological processes in the body. The systematic explanation of the stages of digestion, from mastication to elimination, allows students to follow the journey of food in the body as a whole. With an attractive and informative design, these images enrich knowledge and make complex topics more digestible and fun to learn. According to Hil and Lachenmeier (2022), interesting visualizations can attract attention and motivate students to explore the material further. Moreover, Albers (2015) states that well-designed infographics help to establish connections between concepts, making it easier for students to understand complex information.

The illustration of the tongue organ in the human digestive system, shown in Figure 4, illustrates the role of the tongue in initiating the digestive process. The tongue is the main

tool in chewing and forming the ball of food to be swallowed. Also, it plays a role in stimulating the salivary glands to secrete enzymes that initiate the digestion of carbohydrates. In addition, the tongue also assists in the taste of food, which is important for signaling the body regarding the type of food being consumed.

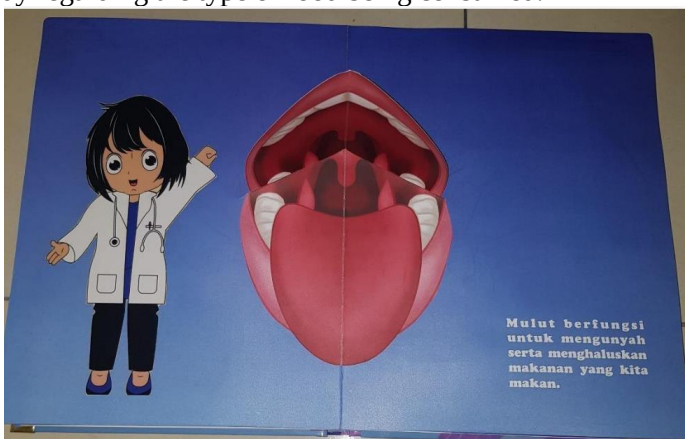


Figure 4 Illustration of the tongue in the human digestive system

Figure 4 shows an illustration page of the tongue organ in the human digestive system, which includes a cartoon character, a large illustration of the mouth, and a brief explanation. On the left side of the book, there is a cartoon character of a smiling little doctor wearing a lab coat, giving a friendly and educational impression. This character serves as a visual guide to explain the information to students. Meanwhile, on the right side, a large 3D illustration of the mouth shows the structure of the teeth and tongue in clear detail. This makes it easier for students to understand the important parts of the mouth. In addition, there is text that explains the function of the mouth, which is to chew and crush food, with concise and easy-to-understand sentences.

The illustrations in this book are designed to help students, especially children, understand the human digestive system visually. Using fun cartoon characters and vivid three-dimensional illustrations is an effective learning aid. With a short explanatory text, the concept of the mouth's function in chewing and crushing food becomes easier to understand. This combination of images and text supports a more engaging and interactive learning process. Schnotz and Wagner (2018) explain that images that complement text can aid the construction of mental models, thus improving understanding of complex concepts.
An illustration of the main human digestive system is shown in Figure 5.

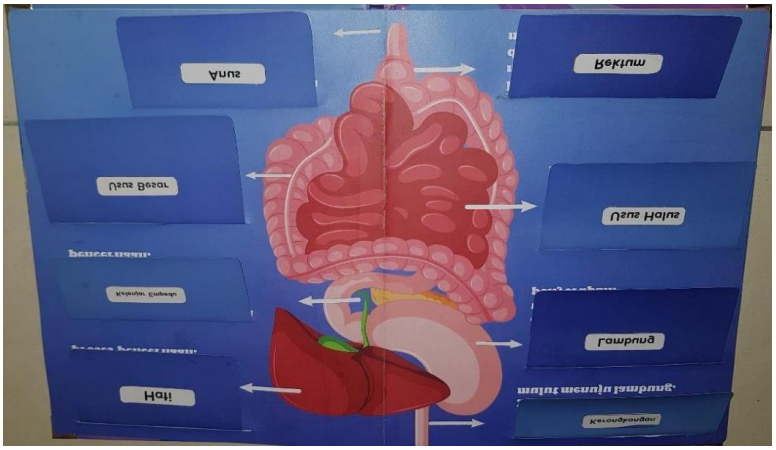


Figure 5 Illustration of the main digestive system in humans

Figure 5 visualizes the human digestive system in vivid detail, featuring key organs such as the liver, stomach, small intestine, large intestine, rectum and anus, complete with easy-to-read labels and arrows to clarify the connection between images and explanations. Additional features, such as retractable flaps, allow students to explore further information on organ function, enhancing interactivity in learning. This design not only aids a deeper understanding of the digestive system but also makes the learning experience more engaging and educational for students.

The last section presents information about the proportion of food in a healthy diet. Figures 6a and 6b show this section.

(a) (b)

Figure 6 Information on food proportions in a healthy diet

Figure 6 presents information on food proportions in a healthy diet, interestingly and educationally. On the left side, a cartoon character of a young doctor wearing a lab coat and glasses serves as a visual guide, providing information on a healthy diet. In the middle is an illustration of a food pyramid showing the proportions of various food groups, such as carbohydrates, vegetables, proteins, and fruits, each colored differently for easy identification. Next to the pyramid, there is information on the ideal percentage of each food group in the daily diet, such as 5% for donuts and steaks, 20% for meat, milk, and eggs, 35% for fruits and vegetables, and 40% for bread, rice, cereals, pasta, oats, and tubers. This design aims to facilitate students' understanding of healthy eating, especially with a fun visual approach and clear and concrete information.

Expert Assessment

The Gregory model agreement index (Retnawati, 2016), based on expert assessment of pop-up book learning media on the material of the human digestive system, is summarized in Table 1.

Table 1 Gregory model agreement index based on media expert assessment

No.	Aspects	Gregory Index
1	Science Aspect	1.00
2	Technology Aspect	1.00
3	Engineering Aspect	1.00
4	Arts Aspect	1.00
5	Mathematics Aspect	1.00

The media expert assessment analysis using the Gregory model agreement results shows that the pop-up book learning media product about the human digestive system fulfills five aspects in the STEAM framework, scoring 1.00 in each aspect. This shows that the pop-up

book media developed is very good at covering the science aspect by presenting accurate material and the latest scientific knowledge. In terms of technology, this pop-up book utilizes interactive design technology that can attract students' attention. In terms of engineering, this product shows the application of engineering principles in designing pop-up mechanisms that function properly. The arts aspect is seen in the creative and attractive visual design, which supports a fun learning experience. Finally, the Mathematics aspect is well integrated by presenting data or mathematical concepts that support understanding the digestive system, such as measuring or comparing organ sizes. With these achievements, this product meets comprehensive learning standards and supports a holistic STEAM approach in education.

Student Assessment

The scoring statistics used in Rasch modelling are shown in Table 2.

Table 2 Scoring statistics used in Rasch modelling

	Item				Person			
	Infit		Outfit		Infit		Outfit	
	MnSq	ZStd	MnSq	ZStd	MnSq	ZStd	MnSq	ZStd
Mean	0.96	-0.02	0.84	-0.24	0.80	-0.50	0.84	-0.43
SEM	0.13	0.25	0.15	0.22	0.19	0.38	0.21	0.40
SD	0.51	0.98	0.60	0.87	0.74	1.48	0.83	1.54

The results of assessing students as potential users of the human digestive system pop-up book media are presented in Figure 7. Figure 7 presents the results of prospective user assessments visualized through the Wright map and the Logit Value of Item (LVI) (Ramdhan et al., 2022). Of the five STEAM aspects, the technology aspect shows the highest average logit value of 1.05 logits, indicating that items in this aspect are more difficult for potential users to agree with. This is due to the limited interactive features in the pop-up book that do not fully reflect the integration of the latest technology in STEAM-based learning. In contrast, the science aspect has the lowest logit value, -0.97 logit, indicating that potential users more easily approve items in this aspect. This is because the presentation of science content in the pop-up book is considered quite informative, systematic, and easy to understand. Visualization of the digestive system that is concrete and relevant to the topic of science learning helps potential users feel helped in understanding the concept thoroughly. As for the other three aspects, namely engineering, arts, and mathematics, they have logit values of -0.63, -0.17, and 0.73, respectively.

In assessing the human digestive system pop-up book media, several indicators show this media's great potential in supporting learning. Indicators Sc1 (science concepts are appropriate to the learning material) and Sc2 (science is conveyed clearly and accurately) reflect the main strengths of this product in communicating science concepts in a way that students easily understand. It uses engaging visual representations to illustrate the processes in the human digestive system, such as digestion in the mouth, stomach, and intestines. Thus, this pop-up book allows students to understand abstract science concepts in a concrete (Agustina et al., 2024) and interactive (Rahmayanti & Setiawan, 2023) way, increasing engagement (Damayanti et al., 2024; Kurniawan et al., 2023) and student understanding of the material (Damayanti et al., 2024; Pratiwi et al., 2023). Wright's map of student assessments as potential users is shown in Figure 7.

In addition, indicators Eng1 (logical and structured design) and Eng2 (clear media creation process) show that this media was designed with a structured and systematic approach. Each element in this pop-up book is logically connected, starting from the anatomical description of the main organs to the human digestive system. This arrangement helps to facilitate the delivery of complex material to students gradually and in order, which

greatly supports learning effectiveness. The process of making media that includes design, development, and evaluation has also been done carefully, showing a careful plan in each stage, which creates a product that is not only attractive but also educational. Each stage supports this in the PjBL model applied to (Diana et al., 2021).

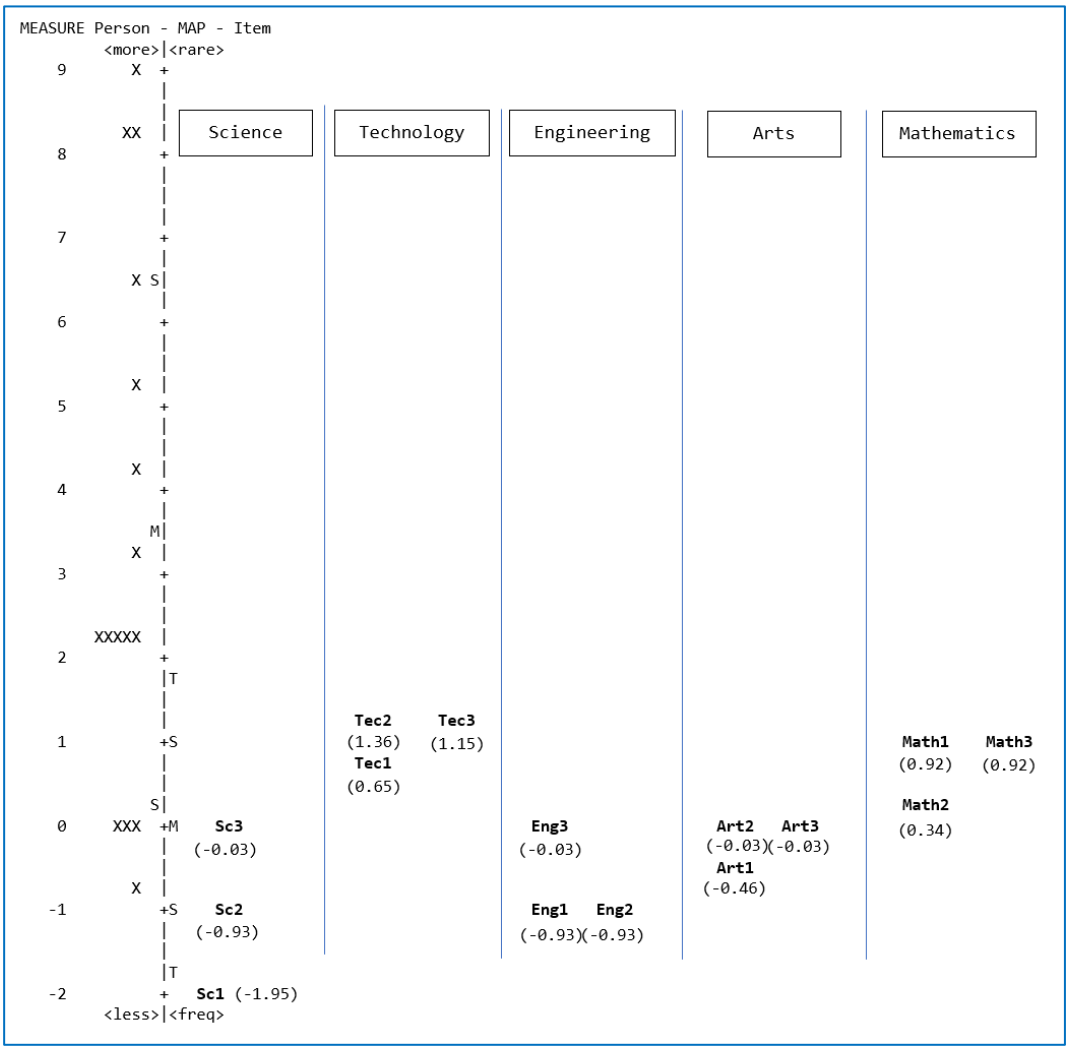


Figure 7 Wright map of student assessment as a prospective user

On the other hand, some challenges need to be considered to improve the effectiveness of pop-up book media, especially related to technological and mathematical aspects. In items Tec2 (ease of use of technology by teachers and students) and Tec3 (exciting new learning experience), the main challenge lies in integrating technology in the pop-up book media format, which is not physically digital. The pop-up book developed is a static media without digital technology to provide further interaction, such as animation, sound, or simulation. The technological features of the pop-up book are limited to the flaps that can be opened and 3D elements that appear or "lift" from the page when the book is opened. This is potentially an obstacle for teachers and students who are used to using more dynamic and interactive learning tools, such as educational apps or technology-based software, such as computers, tablets, or smartboards. Therefore, it does not seem to provide an exciting new learning experience. While technology, such as apps or interactive software, can add value

to learning, pop-up book media focuses more on physical and visual elements that are limited in providing a technology-based learning experience. The use of more interactive technologies, such as augmented reality (AR), can increase engagement and provide a more engaging experience for students (J. et al., 2024; Rohandi et al., 2024), but its application in the context of paper-based and mechanical pop-up books requires greater innovation.

From the mathematical aspect, the challenge lies in applying relevant mathematical concepts in supporting digestive system learning. The mathematical element in the pop-up book is still limited to its use in the pyramid diagram to show information on the ideal percentage of each food group in the daily diet. Indicators Mat1 (mathematics is used to support the delivery of information) and Mat3 (mathematics is used to strengthen logic and problem solving) show the difficulty in integrating clear mathematical calculations in the context of science learning. For example, while concepts such as digestion time or the estimated amount of energy produced from food can be calculated, applying such mathematics in a pop-up book medium focusing on visualization and physical interaction is more difficult. The use of math in a more explicit and integrated form, such as in the form of interactive graphs or tables, does not fully align with the more static design of pop-ups.

Overall, the main technological and mathematical challenges relate to the limitations of the pop-up book media format, which prioritizes physical and visual interaction. However, this does not diminish the potential of this medium to convey science concepts, particularly the digestive system, in an engaging and easy-to-understand way. With the addition of interactive technology elements such as augmented reality or virtual reality and a more in-depth application of mathematics, this product can further optimize its function as an innovative and comprehensive learning tool.

CONCLUSION

This research has produced learning media as a pop-up book based on the STEAM approach in learning human digestive system material for grade V elementary school students. This product successfully combines three-dimensional (3D) visual elements to facilitate students' understanding of abstract concepts in the digestive system. An attractive and informative book design has the potential to increase students' interest in learning and make the learning process more interactive and fun. This pop-up book successfully integrates the five aspects of STEAM. The science aspect is conveyed accurately, technology is optimized through an attractive interactive design, engineering is applied in an effective pop-up mechanism, art is displayed through creative illustrations, and mathematics is inserted in the context of using the size of the illustrations of the organs. This makes this product a comprehensive and educational learning tool.

This study has several limitations, including in the technological aspect, where this pop-up book media has not integrated digital technology such as AR applications or animation, which can increase the interactivity of learning. In addition, the application of mathematics in this media is limited, especially in integrating more explicit mathematical concepts, such as the calculation of digestion time or energy estimation. For future research, it is recommended to integrate digital technology, such as AR or animation, to enrich the learning experience. Applying more in-depth mathematical concepts, such as digestion-related graphs or calculations, can also be considered. In addition, the addition of interactive elements and wider trials in various educational contexts may increase the effectiveness of this media in supporting STEAM-based learning.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT

Conceptualization, MIS and PH; methodology, MIS and RO; formal analysis, RGH, SAP, IM, SW, and W; writing—preparation of the original draft, PH, RO and MIS; and others.

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AUTHOR PROFILES

Dr. Moh. Irma Sukarelawan, M.Pd
irma.sukarelawan@pfis.uad.ac.id
Physics Education Study Program, Universitas Ahmad Dahlan
Expertise: Physics education, Misconceptions, Metacognition, and Rasch modelling
https://scholar.google.com/citations?hl=id&user=mpCvaTcAAAAJ
https://sinta.kemdikbud.go.id/authors/profile/6724533
https://orcid.org/0000-0002-3823-3964
https://www.scopus.com/authid/detail.uri?authorId=57222103626

Dr. Panji Hidayat, M.Pd
panji.hidayat@pgsd.uad.ac.id
Primary School Teacher Education, Universitas Ahmad Dahlan
Expertise: Science Education
https://scholar.google.com/citations?hl=id&user=jn1G4RkAAAAJ
https://sinta.kemdikbud.go.id/authors/profile/6008923
https://orcid.org/0000-0002-3971-1411

Dr. Raden Oktova
r.oktova@pfis.uad.ac.id
Physics Education Study Program, Universitas Ahmad Dahlan
Expertise: Theoretical Nuclear Physics, General Physics, Physics Education
https://scholar.google.com/citations?hl=id&user=VidewEQAAAAJ
https://sinta.kemdikbud.go.id/authors/profile/6041306
https://orcid.org/0000-0002-4629-9912
https://www.scopus.com/authid/detail.uri?authorId=57211976093

Rifdah Gika Nurzannah
2200005169@webmail.uad.ac.id
Primary School Teacher Education, Universitas Ahmad Dahlan
Expertise: Science Education

Sabrina Amelia Putri
2200005171@webmail.uad.ac.id
Primary School Teacher Education, Universitas Ahmad Dahlan
Expertise: Science Education

Ilham Mustaqim
2200005183@webmail.uad.ac.id
Primary School Teacher Education, Universitas Ahmad Dahlan
Expertise: Science Education

Siti Wulandari
2200005184@webmail.uad.ac.id
Primary School Teacher Education, Universitas Ahmad Dahlan
Expertise: Science Education

Wiranda
2211007004@webmail.uad.ac.id
Physics Education Study Program, Universitas Ahmad Dahlan
Expertise: Physics education