



Development of e-comic media on the material of the human excretory system on the problem-solving ability of grade XI students of SMAN 7 Medan

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Abstract. Learning the Human Excretory System material still faces obstacles, including limited variation in learning media and students' difficulty understanding the material's stages and solving problems systematically. This study aims to develop educational e-comic media on the Human Excretory System material to improve the problem-solving abilities of class XI students at SMA Negeri 7 Medan and meet the criteria of validity, practicality, and effectiveness. This study used a research and development (R&D) method with a 4-D model that includes the Define, Design, Development, and Disseminate stages. The study subjects consisted of 29 class XI-3 students at SMA Negeri 7 Medan. The research instruments included validation sheets from media experts, material experts, and instrument experts, teacher and student response questionnaires, and pre-test and post-test tests based on Polya's problem-solving ability indicators. The results showed that the educational e-comic media had an average validity of 96.71%, placing it in the very valid category. The practicality test showed a teacher response percentage of 96.67% and a student response of 96.44%, both in the very practical category. The effectiveness test showed an increase in the average pre-test score from 42.66 to 90.76 in the post-test, with an N-Gain value of 0.83 in the high category. Thus, the educational e-comic media on the Human Excretory System material was declared valid, practical, and effective for use in Biology learning and improved students' problem-solving abilities. The implications of this study indicate that educational e-comic media can serve as an alternative learning medium to support students' problem-solving abilities and as a reference for teachers and researchers developing digital learning media on other materials.

Keywords: *E-comic, Human excretory system, Learning media, Problem-solving skills*

Received: 02 September 2026 Revised: 04 September 2026 Accepted: 05 September 2026 Published: 19 September 2026

INTRODUCTION

Education plays a crucial role in developing students' potential through learning. To meet 21st-century demands, learning must develop higher-order thinking skills, including problem-solving (Chaerunisa & Pitorini, 2022; Chusna et al., 2024). This ability helps students understand problems, determine strategies, implement solutions, and systematically evaluate the results (Aini et al., 2023). In Biology learning, problem-solving skills are essential so that students not only understand concepts but also apply their knowledge to real-life problems (Rahmawati et al., 2018). These skills can be developed through learning media tailored to students' needs (Christiyoda et al., 2016).

The needs analysis results indicate that learning at SMA Negeri 7 Medan still relies heavily on textbooks and PowerPoint presentations. E-comics have not been used, while students still struggle to understand the processes of filtration, reabsorption, and augmentation. This situation indicates a gap between the need for engaging and systematic learning and the available media. Therefore, developing digital media is relevant to support a more systematic and engaging presentation of material (Rahmi & Baharuddin, 2021). In this regard, e-comics can be an alternative medium that combines material with visual elements and a storyline (Tepsing et al., 2026).

Based on these conditions, e-comics were chosen because they combine text,

illustrations, and a storyline in one medium, allowing a more visual and contextual presentation of Biology material. These characteristics align with students' needs in learning the Human Excretory System, which encompasses various processes and concepts that require systematic understanding. Furthermore, a digital format allows for a more interactive and flexible presentation of material than print media. Digital comics in secondary school science lessons have also been developed as a learning medium that supports students' learning experiences (Habiddin et al., 2022). Therefore, e-comics are suitable as a learning medium in Biology, particularly for the Human Excretory System.

Previous research has shown that e-comics on the Excretory System are suitable for use. Mery et al. (2022) demonstrated that an e-comic on the Excretory System met valid criteria based on assessments by subject matter and media experts. Suwanda et al. (2023) developed a digital comic on the same material with a character education orientation. Meanwhile, Pohan et al. (2024) developed a problem-solving-based student worksheet on the Excretory System and found it valid, practical, and effective. Christiyoda et al. (2016) also showed that problem-solving-based learning tools can support the development of critical thinking.

This research is novel in integrating Polya's problem-solving stages into the educational e-comic flow. The product not only presents material on the Human Excretory System but also includes contextual problems, character dialogues, illustrations, and activities that guide students in understanding problems, planning solutions, implementing strategies, and reviewing results. This approach aligns with the principle that visual and digital media can present information more communicatively, while Polya's stages provide a systematic problem-solving framework (Polya, 1973).

Based on this background and these gaps, this study aims to develop an educational e-comic on the Human Excretory System for eleventh-grade students at SMA Negeri 7 Medan and analyze its validity, practicality, and effectiveness in improving problem-solving skills. Practically, the research findings are expected to provide an alternative, innovative and accessible biology learning medium. Academically, this research can serve as a reference for developing digital media based on problem-solving skills.

METHOD

This research employed the Research and Development (R&D) method with the 4D development model developed by Thiagarajan, which consists of four stages: define, design, development, and dissemination. The Four-D model serves as a systematic framework for developing learning products through needs definition, product design, development and validation, and product dissemination (Johan et al., 2023). The product developed was an educational e-comic on the Human Excretory System to improve students' problem-solving skills.

The research was conducted at SMA Negeri 7 Medan with a limited trial of 29 students in grade XI-3. In addition to students, research subjects included media experts, material experts, instrument experts, and a Biology teacher as a practitioner. The research implementation phase followed the 4-D model: Define, Design, Development, and Disseminate. Figure 1 presents these stages.

Define

The define stage involved identifying learning problems in the Human Excretory System in grades XI-3, analyzing needs through questionnaires for teachers and students, and identifying student characteristics, including material understanding, problem-solving skills, and learning interests. The analysis results served as the basis for determining the need to develop educational e-comic media.

Design

The design stage involved drafting the initial structure of the educational e-comic media based on the analysis results from the define stage. The media was designed using Canva and structured according to the Human Excretory System material. The e-comic integrated problem-solving skills into the storyline, character dialogue, and learning activities. This stage also developed a research instrument to obtain data on the media's validity, practicality, and effectiveness.

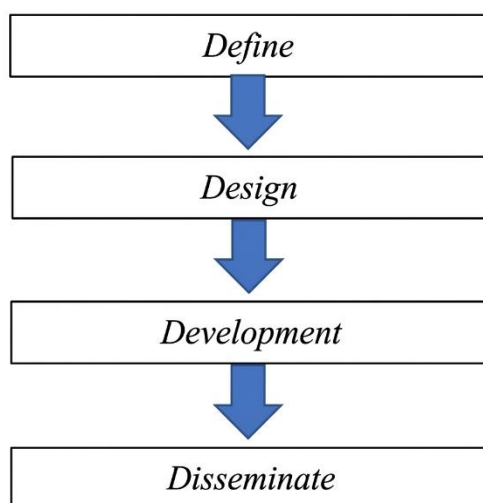


Figure 1. 4-D instructional design (Thiagarajan, 1974)

Development

The development phase involved validating the media and materials to determine product feasibility. The assessment results and validator input served as the basis for revising and refining the media. After revisions, the media was piloted on a limited basis with grades 11-3 of SMA Negeri 7 Medan to obtain responses, suggestions, and comments on using e-comics in learning.

Disseminate

The dissemination stage involves distributing the developed product. Dissemination was limited to students in grades 11-3 of SMA Negeri 7 Medan. The learning process used the media, followed by a review of students' problem-solving abilities and teacher and student responses to its use.

The research instruments consisted of a media expert validation sheet, a material expert validation sheet, a question instrument expert validation sheet, a teacher and student response questionnaire, and a problem-solving ability test. The test consisted of four essay questions structured according to Polya's stages: understanding the problem, planning a solution, implementing the solution, and reviewing. The research data consisted of quantitative and qualitative data. Quantitative data were obtained from expert validation results, teacher and student response questionnaires, and pre- and post-test results. Qualitative data were obtained from suggestions, criticisms, and input from validators and biology teachers.

Media experts and material experts assessed validity using a validation sheet with several indicators and a rating scale. These assessments were used to determine the feasibility of the developed learning media. The entire assessment process used a Likert scale, allowing the scores obtained to be converted into a validity percentage. This validation analysis was carried out using the following techniques:

$$P = \frac{\Sigma x}{N} \times 100\%$$

Description:

P = Percentage of success (%)

x = Total score obtained

N = Maximum score

Table 1 presents the criteria for assessing validity.

Table 1. Product validity criteria

Percentage (%)	Criteria
81–100	Very Valid
61–80	Valid
41–60	Quite Valid
21–40	Less Valid
0–20	Not Valid

Source: Rohmah & Bukhori (2020)

Practical results are interpreted based on the categories in Table 2.

Table 2. Media practicality criteria

Percentage (%)	Criteria
81–100	Very Practical
61–80	Practical
41–60	Quite Practical
21–40	Not Practical
0–20	Not Practical

Source: Nasihah & Utami (2024)

The normalized gain score results are divided into 3 categories, as shown in Table 3.

Table 3. N-Gain criteria

N-Gain score	Criteria
$g > 0.7$	High
$0.3 < g < 0.7$	Medium
$g < 0.3$	Low

Source: Marwani & Adlini (2025)

The N-Gain score results were interpreted in three categories: high, medium, and low. The N-Gain value was used to determine the improvement in students' problem-solving abilities based on pre-test and post-test results after using educational e-comic media. Data from validation, practicality, and effectiveness were then analyzed to determine the quality of the educational e-comic media developed.

RESULTS AND DISCUSSION

This research resulted in an educational e-comic on the human excretory system for eleventh-grade students at SMA Negeri 7 Medan. The media was developed using a 4D model, which includes the define, design, development, and dissemination stages.

During the define stage, the researchers found that the Human Excretory System learning process had progressed well. However, some students still struggled to understand the material because of its many stages and scientific terminology. The teachers used textbooks, PowerPoint presentations, and occasional instructional videos. A student needs analysis

revealed that students needed media with engaging illustrations, easy-to-understand language, and material linked to real-life cases or problems.

During the design stage, the researchers created the e-comic using Canva. The media included a cover, learning outcomes, learning objectives, a concept map, a prologue, character introductions, storyline-based material, and a closing page. At this stage, the researchers also developed a validation instrument to assess the product.

During the development stage, media, material, and instrument experts validated the media. Validation results showed that media experts gave a score of 98.21%, material experts 96.43%, and instrument experts 95%. The overall average validation score was 96.71%, categorized as highly valid. After receiving validator input, the team revised the product before using it in the trial.

E-Comic validity

The product developed is an educational e-comic titled "Body Signals in the Human Excretory System," consisting of 27 pages (Figure 1). This media was developed by combining biology material, illustrations, character dialogue, and everyday-life problems. The presentation helps students understand the material while practicing problem-solving skills through a storyline involving teacher and student characters.

The story begins with an introduction to body signals, then continues with a discussion of the human excretory system, covering the excretory organs, the mechanism of urine formation, disorders of the excretory system, and prevention efforts. The material is presented through dialogue and contextual situations so that biology concepts can be linked to problems encountered in everyday life. At the end, the e-comic concludes with a summary of the excretory system's importance to the body and problem-solving activities. The main characteristics of the developed media are the combination of illustrations, communicative language, and the presentation of scientific concepts. Table 4 below presents the results of the e-comic media validation.

Table 4. E-comic media validation results

Validator	Percentage	Category
Media Expert	98.21%	Very Valid
Material Expert	96.43%	Very Valid
Question Expert	95.00%	Very Valid
Total/Average	96.71%	Very Valid

Based on Table 4, all assessed components were categorized as highly valid. Media expert validation covered graphic and presentation aspects, while material expert validation covered curriculum suitability, conceptual clarity and accuracy, relevance to problem-solving, language and presentation, and integration of illustrations with the material. These results indicate that the e-comic met the eligibility criteria for material, presentation, and evaluation instruments.

The practicality of e-comics

The practicality of the media was determined through teacher and student responses after using e-comics in learning. Table 5 presents the practicality test results.

Table 5. E-Comic practicality test results

Respondents	Percentage	Criteria
Biology Teachers	96.67%	Very Practical
Students	96.44%	Very Practical

Based on Table 5, the teacher response rate was 96.67%, while the student response rate was 96.44%. Both results fall into the very practical category. This indicates that e-comic media is easy for both teachers and students to use and understand in the learning process.



Figure 1. The educational e-comic

The Effectiveness of E-Comics

The effectiveness of the media was analyzed based on improvements in students' problem-solving abilities from pre-test and post-test results. Table 6 presents the results.

Table 6. Results of the e-comic effectiveness test			
Pre-test average	Post-test average	Average N-Gain	Category
42.66	90.76	0.83	High

Based on Table 6, the average pre-test score increased from 42.66 to 90.76 in the post-test. The N-Gain calculation of 0.83 is in the high category. Thus, the educational e-comic media effectively improved students' problem-solving skills in the Human Excretory System topic.

Problem-solving ability based on Polya indicators

The study also analyzed problem-solving ability based on Polya's four indicators. Figure 2 below presents the percentage results for each indicator after using e-comic media.

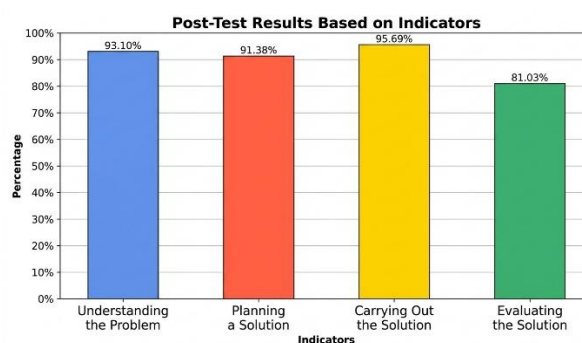


Figure 2. Posttest results for each indicator

The results in Figure 2 show that all problem-solving ability indicators achieved percentages above 80%. The indicator for implementing problem solving achieved the highest percentage (95.69%), while the indicator for re-examining achieved the lowest percentage (81.03%).

The very high validity level indicates that the developed media meets the design, material, and evaluation instrument requirements. These results reinforce [Mery et al. \(2022\)](#), who found that e-comics on the Excretory System met the eligibility criteria through expert validation. [Suwanda et al. \(2023\)](#) also showed that digital comics on the Excretory System can serve as learning media. This study differs in its product orientation, which specifically integrates problem-solving skills into the media flow.

Product quality depends not only on visual appearance but also on the material's appropriateness and how problems are presented. The developed e-comic combines illustrations, dialogue, and everyday life problems. This presentation allows multi-stage concepts, such as the mechanism of urine formation, to be presented sequentially. These findings align with [Ayu et al. \(2024\)](#), who demonstrated that e-comics can be a viable digital learning medium to support Biology learning.

The media's practicality was categorized as very practical. The high teacher response indicates that the media can help deliver complex material more systematically. High student responses indicate that the visual display, communicative language, and storyline were well-received. These results align with research by [Pohan et al. \(2024\)](#), which showed that problem-solving-based tools for the Excretory System received a positive response from both teachers and students.

The media's effectiveness was evident in the increase in average scores and N-Gain. The increase from 42.66 to 90.76, with an N-Gain of 0.83, fell within the high category. These results show that e-comics not only deliver material but also provide context in which students can apply concepts. These findings align with [Christiyoda et al. \(2016\)](#), who demonstrated that problem-solving-based learning tools can support the development of critical thinking skills.

Based on Polya's indicators, implementing solutions showed the highest achievement (95.69%), while reviewing showed the lowest (81.03%). The high achievement in the implementing solutions stage was supported by the e-comic presentation, which included contextual problems, illustrations, dialogues, and questions that guided students to connect the Human Excretory System concept to the problem and determine appropriate actions. Meanwhile, the low achievement in the reviewing stage was because some students listed only 2–3 methods, whereas the assessment rubric assigns the maximum score to students who list

4–5 methods. This indicates that students provided several appropriate methods, but not all met the criteria for answers that qualify for the maximum score (Polya, 1973).

Overall, the contextual problems in the e-comic gave students opportunities to understand the problem and determine solutions (Rizcallah & Parlak, 2025), which supported improved problem-solving skills. This is shown by the increase in the average value from 42.66 in the pre-test to 90.76 in the post-test, with an N-Gain of 0.83 in the high category, so that the developed media can be used as a learning medium to support students' problem-solving abilities in the human excretory system material.

CONCLUSION

This study produced an educational e-comic media on the human excretory system material for grade XI students of SMA Negeri 7 Medan using the 4D development model. The developed media was declared very valid and very practical based on assessments by the validator, Biology teacher, and students. Using e-comic media also improved students' problem-solving abilities, with an N-Gain value of 0.83 in the high category. Thus, educational e-comic media can serve as an alternative Biology learning medium to support students' problem-solving abilities. The implications of this study indicate that teachers can use e-comic media as an alternative learning medium that supports the learning process and students' problem-solving abilities, and as a reference for developing digital learning media on other Biology materials. Further research is recommended to develop e-comic media on different Biology materials and apply them to different educational levels with a larger sample size.

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