

DEVELOPMENT OF DIGITAL COMIC LEARNING MEDIA BASED ON MOBILE LEARNING ON MEDIA: MAKING MEDIA MATERIALS IN PLANT TISSUE CULTURE

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ARTICLE INFO	ABSTRACT
<p>Article History: Received 20/05/2025 Revised 22/07/2025 Approved 24/08/2025 Published 27/09/2025</p> <hr/> <p>Keywords: Mobile Learning, Digital Comic, Feasibility, ADDIE, Plant Tissue</p>	<p>This research was conducted based on student needs analysis, analysis of learner characteristics, and curriculum analysis, namely the lack of visualization and presentation of concepts and the lack of utilization of interactive technology in the learning process on media material and media making in tissue culture for college students. This study intends to develop digital comic media based on mobile learning and making media materials in tissue culture. This research method used research and development (R&D) with the ADDIE model: analyze, design, develop, implement, and evaluate. The subjects of this study were students of the Department of Biology, Universitas Negeri Medan, with a sample of 39 people who were given digital comics based on mobile learning. The results showed that digital comics that had been tested for feasibility by material experts are included in the worthy category; instructional experts are included in the very worthy category; media experts are included in the very worthy category; responses from lecturers of tissue culture courses are included in the very good category; and students based on individual tests are included in the very good category, small group tests are included in the very good category, and limited group tests are also included in the very good category. Additionally, the pre-test and post-test results showed an N-Gain of 0.64, which falls into the medium category.</p>
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INTRODUCTION

Innovation in learning media is currently necessary to keep pace with the ongoing developments in science and technology (Pangalo, 2020; Alenezi et al., 2023). Developing learning media with technological principles through mobile phones makes it easier to deliver educational content (Neffati et al., 2021). Learning methods can be broadly categorized into e-learning systems (Rasheed & Wahid, 2021; Liu & Yu, 2023), which involve the use of electronic devices and digital media for learning, and mobile learning (m-learning), which specifically utilizes mobile communication devices and technologies. Mobile learning is a flexible alternative that allows learning services to be accessed and utilized anywhere and anytime (Okai-Ugbaje et al., 2022; Syafruddin, 2024). The presence of m-learning is intended as a complement to existing learning and provides opportunities for students to relearn material that is not mastered anywhere and anytime. This type of technology can certainly provide a different experience in the learning process (Ardiansyah & Nana, 2020; Criollo-C et al., 2021).

The analysis of student needs, conducted through questionnaires distributed to students who have taken tissue culture courses in the Biology Department of Universitas Negeri Medan, revealed an average score of 71.5% regarding their difficulties in understanding media material and creating media for tissue culture. Additionally, the analysis of student characteristics through distributed questionnaires revealed an average score of 75.3% regarding their interest in and



utilization of digital media in the learning process. This result is because students often look for additional digital learning resources to deepen their understanding of tissue culture material, especially in media and making media materials. Lastly, based on the results of curriculum analysis through interviews with one of the lecturers of tissue culture courses in the Biology Department of Universitas Negeri Medan, information was obtained on the delivery of theory. Students do show enthusiasm, but they also expect practicum activities to measure skills. The practicum cannot be carried out due to the limited facilities needed for the tissue culture practicum. Therefore, learning media equipped with pictures is needed. One of them is comic media, which can complement learning because it presents visualization through images (Suri et al., 2021; Agustini et al., 2021). The described problems demand a suitable solution. One appropriate solution to meet the needs of students as a learning subject is designing and developing more interactive learning media based on mobile learning, namely digital comics.

Comics can be a medium that attracts everyone’s attention in terms of age because they have an advantage, namely being easy to understand (Prihantini et al., 2025). Comics combine visual and narrative elements to convey information in an engaging way (Cohn, 2020; Anggraini & Zulyusri, 2023). This digital comic media can be read anytime and anywhere, which allows students to repeat the material without having to depend on the lecturer’s explanation in class (Agustin et al., 2023). When creating comics, the content must align with the material being used; suitable material includes abstract and complex concepts that require visualization, connections to everyday life to enhance understanding, elements that attract students' interest to motivate learning, opportunities for critical thinking and problem-solving, and resources for independent learning to provide students with greater flexibility (Guntur et al., 2023).

Tissue culture is a method to propagate or cultivate plants by utilizing small parts of the plant's tissues or cells that have identical characteristics to the parent plant (Manohar et al., 2024; Prashant & Bhawana, 2024; Kavinaya Shri et al., 2025). This process is carried out under sterile conditions by isolating certain parts of the plant, such as roots, stems, leaves, or shoots, so that these parts can develop and grow into new plants that have the same properties as their parents (Harahap et al., 2024). The challenge in understanding this material is its complex and abstract nature, making it difficult to learn through traditional learning methods such as texts or lectures. To help students visualize and understand the processes and concepts taught, more interactive and visual learning media are needed (Hasanah & Sudira, 2021; Arsyad et al., 2024). The digital comics based on mobile learning are one of the relevant solutions because they can turn complex concepts into more concrete and narrative visualizations (Mamolo, 2022; Apostolou & Linardatos, 2023; Krysty et al., 2025). Media like such comics can help connect theory with practice effectively and make learning engaging and easy to follow.

Building upon research conducted by Suwanda et al. (2023), the application of digital comic media in biology lessons with a focus on educational characters regarding excretory systems has proven to be effective in increasing the character value of students with an average percentage of expert validation, which is 86.34%. Research conducted by Irfana et al. (2017) also supports the effectiveness and feasibility of using this digital comic media as a biology learning medium in high school, and it can serve as supporting material for independent learning. In addition, the use of digital comics received positive responses from both teachers and students.

METHOD

This type of research is called Research and Development (R&D) using the ADDIE model with research procedures in the form of analyzing, designing, developing, implementing, and evaluating. This research has been carried out at the Biology Department, Faculty of Mathematics and Natural Science, Universitas Negeri Medan, as a sample analysis of product needs. The product has been tested in the PSPB 2022 class consisting of 39 students in the tissue culture course.

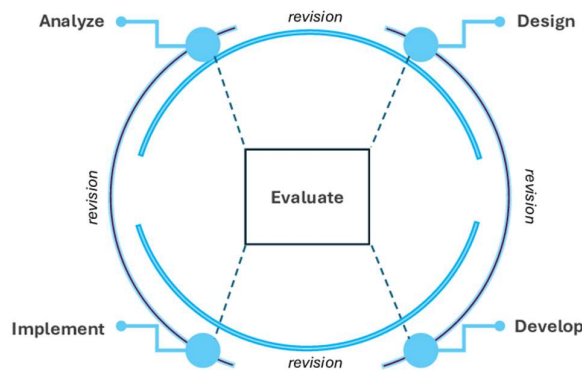


Figure 1. ADDIE Model (Branch & Varank, 2009)

The data analysis in this study consisted of validity data analysis by material expert, instructional expert, and media expert; response data by lecturer and students divided into individual trial, small group trial, and limited group trial; and effectiveness test analysis using N-Gain. To determine the effectiveness of the digital comic, it was tested using a pretest and posttest consisting of 10 essay questions. The normalized N-Gain formula is used in this research, which can be seen below.

$$NGain = \frac{Posttest\ Score - Pretest\ Score}{Ideal\ Score - Pretest\ Score}$$

After the calculation is complete, the N-Gain criteria can be seen in Table 1.

Table 1. Criteria for Normalized Gain

N-Gain Value	Interpretation
$0,70 \leq g \leq 100$	High
$0,30 \leq g < 0,70$	Medium
$0,00 < g < 0,30$	Low

RESULTS AND DISCUSSION

Results

Research on mobile-based digital comic learning material begins with analysis. This stage includes a needs study, student characteristics analysis, and curriculum analysis. This stage showed that the lack of visualization and presentation of concepts makes it hard for students to master media and making media in plant tissue culture, and that the learning media is still less interactive due to the lack of interactive technology, so digital comics are needed as a supporting learning media. Figure 2 depicts comic digital learning media cover design.



Figure 2. Digital Comic Learning Media Cover Design

This digital comic has numerous sections: cover, initial information, how to use, learning outcomes, sub-learning outcomes, comic characters, synopsis, table of contents, Chapters include Basic Concepts of Plant Tissue Culture, Plant Tissue Culture Media, Making Plant Tissue Culture Media, a glossary, a bibliography, and a quiz at the end of each chapter. After that, Google Sites stores and publishes digital comics. You can read the comic online or download the PDF on the same page. The comic works on cellphones, laptops, tablets, and iPads. After design, specialists evaluate the product's practicality during development.

Feasibility Test by Material Expert

The following are the results of the review and evaluation given by the material expert on the digital comic product can be seen in Table 2.

Table 2. Results of digital comic assessment by material expert

No	Aspects	Score				Number of Questions	Total Score	Max Score	Average (%)	Criteria
		4	3	2	1					
1	Presentation of material	1	7	0	0	8	25	32	78,12	Worthy
2	Appropriateness of material	2	2	0	0	4	14	16	87,5	Very worth it
Total						12	39	48	81,25	Worthy

Based on Table 2 data. Material specialists rate material presentation at 78.12% and appropriateness at 87.5%, respectively. The average of these three factors is 81.25%, making it worthy. The validator's assessment yielded suggestions or input that were used to improve the digital comic media generated, indicating that it was feasible to test with trial process adjustments.

Feasibility Test by Instructional Expert

The results of the assessment and evaluation conducted by the instructional expert on the digital comic product are presented in Table 3.

Table 3. Results of digital comic assessment by instructional expert

No	Aspect	Score				Number of Questions	Total Score	Max Score	Average (%)	Criteria
		4	3	2	1					
1	Compliance with the scientific approach	3	0	0	0	3	12	12	100	Very worth it
2	Quality of motivating students	2	0	0	0	2	8	8	100	Very worth it
3	Media can help	3	0	0	0	3	12	12	100	Very worth it
4	Active involvement of students	0	2	0	0	2	6	8	75	Worthy
Total						10	39	40	95	Very worth it

In accordance with the information presented in Table 3. The media aspect can help by 100%, the quality aspect motivates students by 100%, and the aspect of conformity with the scientific approach is given an average of 100% by instructional experts. The active student involvement aspect is 75%, which indicates that it is worthwhile, while the percentage of the three aspects falls into the "very worth it" category. The average value of the four aspects is 95%, indicating that it is highly valuable. The validator's assessment yielded suggestions or input that were employed as a basis for the enhancement of the digital comic media that was created. He ultimately determined that digital comic media was viable for testing with modifications for the trial process.

Feasibility Test by Media Expert

The following are the results of the review and evaluation given by the media expert on the digital comic product can be seen in Table 4.

Table 4. Results of digital comic assessment by media experts

No	Aspect	Score				Number of Questions	Total Score	Max Score	Average (%)	Criteria
		4	3	2	1					
1	Media Display	7	2	0	0	9	34	36	94,4	Very worth it

2	Learning Media Design	1	6	0	0	7	22	28	78,57	Worthy
3	Language Writing and Presentation	1	3	0	0	4	13	16	81,25	Worthy
Total						20	69	80	86,25	Very worth it

Building upon Table 4 data, media experts rate media presentation at 94.4%, indicating that it is worth it. Learning media design scored 78.57%, and writing and language presentation scored 81.25%, indicating that these two areas are worthy. According to these three factors, the average value is 86.25%, making it highly worthwhile. Based on the validator's assessment, ideas or feedback were used to improve the digital comic media generated, which he felt was feasible to test with trial process updates.

Implementation stages involve product trials or responses to digital comics given to lecturers and students, who are divided into three groups: 3 students, 10 students, and 20 students from PSPB 2022. A biology class at Universitas Negeri Medan's Faculty of Mathematics and Natural Science.

Lecturer Response

The following are the results of the lecturers' response to digital comics that can be seen in Table 5.

Table 5. Lecturers' response to digital comics

No	Aspect	Score				Number of Questions	Total Score	Max Score	Average (%)	Criteria
		4	3	2	1					
1	Digital comic display	1	3	0	0	4	13	16	81,25	Very good
2	Comic language Use of	2	7	0	0	9	29	36	80,56	Good
3	digital comic media	2	1	0	0	3	11	12	91,67	Very good
Total						16	53	64	82,81	Very good

Table 5 shows that the lecturer's average rating for digital comics display is 81.25% very good. Good comedy language averages 80.56%. Digital comic media use was 91.67% very good. Lecturer responses yielded an average of 82.81% in the very good category for these three factors. These findings suggest that digital comic media can support plant tissue culture instruction in the classroom.

Student Response

Individual Trial

The following are the results response to digital comic from individual trials that consist of 3 students can be seen in Table 6.

Table 6. Individual Trial Result

No	Aspect	Score				Number of Questions	Total Score	Max Score	Average (%)	Criteria
		4	3	2	1					
1	Digital comic display	6	6	0	0	12	42	48	87,5	Very good
2	Digital comic presentation	13	5	0	0	18	67	72	93,5	Very Good

No	Aspect	Score				Number of Questions	Total Score	Max Score	Average (%)	Criteria
		4	3	2	1					
3	Use of digital comic media	10	15	0	0	15	55	60	91,6	Very good
Total						45	164	180	91,1	Very good

Table 6 indicated that the mean percentage derived from individual trials regarding the visual aspect of digital comics was 87.5%. The digital comic presentation achieved a score of 93.5%. The utilization of digital comic media achieved a proportion of 91.6%. The three aspects identified as part of the criteria are commendable. The average results from individual trials, including three participants, are 91.1%, indicating very acceptable criteria. Digital comics can serve as a supplementary educational medium in plant tissue culture courses during the learning process.

Small Group Trial

The following are the response to digital comic from small group trial that consists of 10 students can be seen in Table 7.

Table 7. Small Group Trial Result

No	Aspect	Frequency				Number of Questions	Total Score	Max Score	Average (%)	Criteria
		4	3	2	1					
1	Digital comic display	24	16	0	0	40	144	160	90	Very good
2	Digital comic presentation	45	15	0	0	60	225	240	93,75	Very Good
3	Use of digital comic media	34	16	0	0	50	184	200	92	Very good
Total						150	553	600	92,16	Very good

The mean percentage derived from small group trials on the visual aspect of digital comics was 90%. The presentation of digital comics achieved a percentage of 93.75%. The utilization of digital comic media achieved a proportion of 92%. The three aspects identified as part of the criteria are commendable. The average statistics from the small group trial of 10 individuals are 92.16%, indicating very good criteria. Digital comics can serve as a supplementary learning medium in plant tissue culture courses throughout the educational process.

Limited Group Trial

The following are the responses to digital comic from limited group trial that consists of 20 students can be seen in Table 8.

Table 8. Limited Group Trial Result

No	Aspect	Frequency				Number of Questions	Total Score	Max Score	Average (%)	Criteria
		4	3	2	1					
1	Digital comic display	37	43	0	0	80	277	320	86,56	Very good
2	Digital comic presentation	58	62	0	0	120	418	480	87,08	Very Good
3	Use of digital comic media	53	47	0	0	100	353	400	88,25	Very good
Total						300	1048	1200	87,33	Very good

Table 8 shows that the limited group trial averaged 85.56% for digital comics display. The digital comic presentation rate was 87.08%. They also scored 88.25% in the digital comic medium. Very good in the three criteria. According to these comments, the small group trial of 20 people averaged 87.33% with extremely good criteria. Thus, plant tissue culture classes can benefit from digital comics.

Evaluation concludes the ADDIE development model. This phase tested if the digital comics improved tissue culture course learning for Medan State University biology students. A pretest and posttest of 10 essay questions were given to 39 PSPB 22 A students in the Biology Department, Faculty of Mathematics and Natural Science, Universitas Negeri Medan, to test effectiveness. N-Gain was used to assess pretest and posttest findings to estimate digital comics' effectiveness. Table 9 shows the N-Gain test results.

Table 9. N-Gain results of student learning outcomes

N-Gain Classification	Amount	N-Gain Average	Criteria
High	12		
Medium	27	0,64	Medium
Low	0		

Table 9 indicates that 12 students experienced an increase in learning outcomes in the high category, while 27 students showed improvement in the medium category, and none were reported in the low category. Therefore, overall, the average improvement in learning outcomes for the PSPB 22 A class students in the Biology Department, Faculty of Mathematics and Natural Science, Universitas Negeri Medan, totaling 39 individuals, is 0.64, which falls into the medium category.

Discussion

This development research creates a mobile-learning-based digital comic medium for plant tissue culture. The major goal of this development is to promote student learning. Digital comics facilitate lecturer-student engagement. We use the five-step ADDIE approach in development: Analyze, Design, Develop, Implement, and Evaluate.

The foundation of this mobile learning-based digital comic lies in analysis. After analyzing learning objectives, needs, learner characteristics, and curriculum, it was found that most students struggle to understand tissue culture media due to a lack of direct practice and representative visual media. From this point, a mobile learning digital comic was created with three chapters: plant tissue culture basics, media, and media production. Text-based and lecture-based instructional materials fail to engage students; hence, this condition is vital while creating them. According to Akram et al. (2022), Ranesa et al. (2022), a teaching and learning system that integrates education, and technology will be easier to understand.

After the analysis, this digital comic aims to blend visual and narrative aspects to make it interesting and easy to understand. Storyboarding, character creation, illustration coloring, and tale learning are part of design. In the story, Mrs. Ranti lectures on tissue culture media slowly and clearly. This clip was created using Canva for excellent visual design and Google Sites for flexible distribution across devices. Instructions, learning outcomes, main material, and a QR code to the evaluation task are in the comic. With an A4 display and many fonts, this product's visual appearance suits digital reading. The supervisor reviews and comments on the original design. The feedback was utilized to improve digital comics before expert lecturers assessed their practicality during development.

The next stage is development. This stage of development involves professional feasibility testing. Material, instructional, and media professionals tested the digital comics' practicality. Material specialists evaluate appearance and suitability, notably media material and plant tissue culture medium manufacturing. According to Fitria et al. (2023), material presentation includes imagery, contextual narrative, and student emotional participation with stories. Instructional specialists evaluate scientific approach, student motivation, media support, and student interaction. Hidayat & Rostikawati (2018) found that the digital comic medium with a scientific methodology improved students' science ability, particularly in knowledge and attitudes. Digital comics also help students grasp science and enhance cognitive, emotional, and behavioral engagement. Media specialists evaluate media display, studying media design and writing, and language presentation last. According to Rasmet et al. (2025), comics with appealing images, student-relevant colors, and proportionate layouts boost learning engagement. Then, using basic, plain language that matches kids' cognitive levels makes the subject easier to absorb.

The feasibility test of this digital comic media by three experts—material, instructional, and media—found that material experts gave an average score of 81.25% (worthy category), indicating that the content met learning needs and was feasible to implement. Instructional professionals scored this material 95% (extremely worth it) because it

encourages student participation and follows the scientific method. Media experts gave look, design, and linguistic presentation an average of 86.25% (extremely worth it). These three tests show that digital comic material can be tested in the classroom.

Then comes implementation. After expert lecturers declare digital comics feasible, the next step is to ask 1 lecturer and students for responses, which are divided into 3 groups: individuals (3 people), small groups (10 people), and large groups (20 people). The lecturer's response proves that digital comics promote learning well. The lecturer's response focused on digital comics' appearance, language, and use. The professor gave this media an average score of 82.81% for very good, indicating that it presented tissue culture topics in an interesting, effective, and acceptable manner. In addition to the lecturer's answer, individual, small group, and limited group student trials demonstrated great satisfaction.

In individual trials, student satisfaction averaged 91.1%, while in small and big groups it was 92.16% and 87.33%. This indicates that this digital comic is easy to use and makes learning stuff exciting and understandable. This good answer shows that mobile learning can improve classroom learning. According to Lestiani et al. (2021), kids appreciated reading digital comics because they were not dull and enjoyed studying with them.

The final step is evaluation. This stage involves testing the digital comics' efficiency by having 39 students from PSPB 22 A class, Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Medan, answer 10 essay questions pre- and post-test. The effectiveness test measured learning outcomes improved using pretests and posttests. Based on N-Gain analysis, the average improvement was 0.64, which is moderate. Interestingly, no pupils scored low. This suggests that all kids who use digital comic media learn more, but in different ways.

CONCLUSION

We are building upon the validation results from material experts, instructional experts, and media experts, as well as the responses from tissue culture lecturers and students, who participated in individual, small group, and limited group trials. The digital comic learning media based on mobile learning on media and making media materials in plant tissue culture can be used as supporting learning media for students of the Biology Department, Universitas Negeri Medan.

As a suggestion, teachers can use mobile learning-based digital comic learning media to increase student engagement and understanding of plant tissue culture. This research can help improve the quality of learning in schools by using mobile-based digital comic learning media. Further research can be conducted to develop mobile learning-based digital comic learning media for other materials in biology or other sciences. In addition, further research can be conducted to develop more effective tools for measuring student understanding after using mobile learning-based digital comic learning media on plant tissue culture.

AUTHOR CONTRIBUTIONS

All authors participated in the conceptualization, design, data collection, analysis, interpretation, writing, and revision of the article. All authors approved the finalized manuscript.

CONFLICT OF INTEREST STATEMENT

The author claims there are no conflicts of interest regarding the publishing of this paper. The oversight and assistance provided by supervisors fulfilled their professional responsibilities, and no financial, personal, or other affiliations influenced the research and results presented in this work. We have applied maximum effort to conduct and present the research with the highest standards of integrity and transparency.

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