Assimilation: Indonesian Journal of Biology Education
ISSN 2621-7260 (Online)
Journal homepage: https://ejournal.upi.edu/index.php/asimilasi

# Development of digital comic learning media based on mobile learning on sterilization and explant planting materials in plant tissue culture courses

**Aura Albizia Tanjung, Fauziyah Harahap*, Zhafira Khalisyah, Syakila Anwar, Aura Nazwari, Fadilah Pasaribu, Naila Zahwa Sitompul**
Study Program of Biology Education, Faculty of Mathematics and Natural Science, Universitas Negeri Medan, Willem Iskandar Street, Pasar V, North Sumatra 20221, Indonesia
*Corresponding author: fauziyahharahap@unimed.ac.id

OPEN ACCESS

## ARTICLE HISTORY
Received:
First Revised:
Accepted: 30 July 2025
First Available Online: 31 July 2025
Publication Date: 31 July 2025

## KEYWORDS
Digital comics
Learning media
Mobile learning
Plant tissue culture

## ABSTRACT

This research aims to develop a digital comic by determining the feasibility and the effectiveness of using material in the plant tissue culture to help students understand the material presented in the course at the Department of Biology, Universitas Negeri Medan. Data collection techniques include observation, giving questionnaires, and giving instruments to instructional experts, material experts, and media experts. The research method used is Research and Development (R&D), which uses the ADDIE development model. This development research resulted in the creation of a digital comic learning media based on mobile learning focused on sterilization and planting materials, developed using the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model. Feasibility test results indicated high approval ratings: 93.75% from instructional experts in the “highly feasible”, 84.5% from material experts in the “highly feasible”, and 95.4% from media experts in the “highly feasible”. Lecturer responses were also favorable, with scores of 79.9. Student responses were also highly favorable, with scores of 91 from an individual group, 90.2 from a small group, and 94.2 from a limited group. Based on the data analysis, digital comic learning media based on mobile learning is effective enough for use in plant tissue culture courses.

## INTRODUCTION

The education sector is highly correlated with technology and the internet, so information can be accessed easily by students (Simatupang et al., 2023). Education is currently closely related to the digital era, where information and communication technology continue to develop. Developments in this field require teachers to assist students in the adjustment process by mastering various skills needed to succeed in learning. One of the technological innovations that is widely used by educators in the world of education is learning media (Imboy et al., 2025).

Many factors contribute to the success of a learning process, and one of them is the media. The use of media as a tool that can facilitate material communication also influences motivation and interest in learning, known as learning media. Learning media itself is a means of communication that can be in print or visual form, including hardware technology (Harahap & Saragih, 2023). Learning media can be understood as a means of conveying messages that include learning materials so that the goals of the learning process can be achieved (Dewi & Harini, 2021). The use of media in learning can make the learning process more interesting and fun (Amalia et al., 2022). The selection of the right media must also be a concern because appropriate media can have a positive influence on the quality of learning (Wijaya et al., 2020). Based on the experience expressed by Edgar Dale, there is an explanation that the use of learning media equipped with pictures can increase students' memory by up to 30% when compared to reading, which only reaches 10%. One of the innovations in technology-based visual learning media that can be developed by educators is digital comics (Anggraini & Zulyusri, 2023). Currently, comics have become one of the media that attracts the attention of learners (Raneza et al., 2022). Comics are a type of visual communication media that has an attractive appearance and is arranged in order to convey information to readers. Educational comics serve to address comprehension issues, as their simple, clear, easy-to-understand, and personalizable nature makes them informative and educational (Damayanti & Kuswanto, 2021)

. On the other hand, digital comics were chosen as one of the innovations in learning media, considering their proximity to students and current technological developments (Rofiqoh & Kiptiyah, 2024). Digital comics are considered an effective learning media in helping to understand abstract material, as well as adapting to technology so that they provide practical, flexible, and easily accessible properties (Nurinayati et al., 2018). Comics function as a learning media that can support students in learning, both in the classroom and outside the classroom (Badeo & Koc, 2021). Comics can be applied in the two-way learning process, acting as a teaching tool and learning media that can be used by students independently (Syahriani & Sofyan, 2020).

The use of mobile devices in the world of education is known as mobile learning. Mobile learning is a flexible and accessible tool (Rifai et al., 2020). The use of technology such as the Internet, in improving educational achievement has increased rapidly (Harahap et al., 2019). Learning media that use digital comics have several advantages when compared to print comics. For example, digital comics tend to be more durable, more environmentally friendly, more practical, easier in the distribution process, and more efficient or economical (Damanik & Sipahutar, 2022). Therefore, digital comic media based on mobile learning is a special learning tool because students can access the material whenever and wherever they are (Rifai et al., 2020).

The tissue culture course is one of the mandatory courses in the Biology Education study program, Universitas Negeri Medan. Based on the analysis of student needs and student characteristics through the distribution made by researchers, in addition, 88.4% of students need interactive learning media, and given the amount of material presented in the course, learning is still going on, with boring and causes students to be bored quickly. As many as 73% of students consider the concept of sterilization and material explanation as one of the aspects of biology that is quite challenging and complex. In addition, 90.9% of students have been able to use technology and digital media, and 91% of them prefer learning that is hands-on practice. Based on the results of observations through interviews conducted with lecturers in the Tissue Culture course at

DOI: https://doi.org/10.17509/10.17509/aijbe.v8i2.83847
e-ISSN 2621-7260

Universitas Negeri Medan, the tissue culture course consists of 2 credits, and there is no tissue culture laboratory. The tissue culture course learning process is still through reading books, PowerPoint, and videos. Digital comics can also be used as an effective alternative for elaborating the mini research process and can complement the lack of technological facilities in learning in the plant tissue culture course. Comic-based learning media or digital comics have been widely developed by containing biological materials on the respiratory system, such as research by (Utariyanti et al., 2015) who have developed comic-based learning media in respiratory system materials. However, few studies have developed mobile-based digital comics specifically for abstract and procedural topics in biology, such as sterilization and explant planting in tissue culture courses.

Based on the problems that have been explained and the potential of comics in education, this study aims to create learning media in the form of digital comics. The use of comics in courses that emphasize hands-on skills, such as network culture, has a strong rationale as a learning support media (Hidayat et al., 2024). While hands-on practice in the lab remains the main focus, an early understanding of the procedures, tools, and stages of work is essential for students to be able to undergo the practice with confidence and more purpose. Comics, as a narrative visual medium, are able to present complex information in a simpler and more interesting way, making it easier for students to understand the workflow and potential errors that may occur (Damopolii et al., 2021).

Digital comics were chosen because they can attract students' attention and help them understand the material being taught. With attractive visuals and interactive stories, this digital comic is expected to overcome the shortcomings of learning media about tissue culture in the Biology Department of Universitas Negeri Medan. This study applies the Research and Development (R&D) method with the ADDIE development model (Analysis, Design, Development, Implementation, Evaluation). This model was chosen because it is structured and efficient in producing good learning media products. During the development stage, data were collected through observation, questionnaires, and assessment tools from experts in the fields of learning, materials, and media to assess the feasibility of the media being developed. Thus, this study makes a significant contribution to the innovation of learning media, especially in the material on sterilization and planting of carrot explants in plant tissue culture. It is hoped that this digital comic media can improve students' understanding and interest in learning, thus creating a more enjoyable and efficient learning experience.

## METHODS

This type of study is research and development (R&D). Research and development (R&D) is a form of research whose steps are used to create or improve new or existing products. The development model applied in making this digital comic is the ADDIE model, which includes five stages: analysis, design, development, implementation, and evaluation (Damanik et al., 2024). This research was conducted at the Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Medan, as an example to analyze product needs. This product will be tested in the Biology Education 2022 D class, consisting of 26 students in the tissue culture course. The purpose of this study is to increase the value of the product and evaluate the effectiveness of mobile-based digital comic learning media in the learning process of sterilization and planting carrot explants.

In the analysis phase, questionnaires were distributed to students, and interviews were conducted with tissue culture lecturers. Variables based on the tissue culture RPS (Semester Learning Plan), digital comic media needs, student characteristics, and problems that arise in tissue culture lectures are analyzed. In the design phase, a digital comic draft is prepared by preparing the theme, tools, storyboard, and illustrations to be developed using the Canva and Medibang Paint apps. In the development phase, the digital comic that has been created is validated by instructional experts, material experts, and media experts. In the implementation

DOI: https://doi.org/10.17509/10.17509/aijbe.v8i2.83847
e-ISSN 2621-7260

phase, the digital comic is evaluated by tissue culture lecturers and students through field trials consists of an individual group, namely 3 people from biology education class A 2022, a small group of 10 people from the bilingual biology education class 2022, and a limited group of 20 people from biology education class D 2022. In the evaluation phase, the effectiveness of the digital comic is tested on students in the biology department.

Data analysis in this study consisted of validity data analysis by instructional experts, material experts, and media experts, data analysis of tissue culture lecturer and student responses using a Likert scale, and effectiveness test analysis using N-Gain. The Likert scale aims to provide a range of values with categories of very unfeasible, unfeasible, feasible, and very feasible for digital comic that have been validated by experts. The digital comic being developed can be assessed as appropriate if they are in the "Feasible" and "Very Feasible" categories according to Table 1 (Akbar, 2022).

**Table 1.** Likert Scale Validity Test

| Scale Range | Categories |
|---|---|
| 25 - 43.75 | Very Unfeasible |
| 43.76 - 62.5 | Unfeasible |
| 62.6 - 81.25 | Feasible |
| 81.26 - 100 | Very Feasible |

The next data analysis is based on lecturer and student responses, which are carried out based on field trials. the questionnaire scores obtained will be interpreted in several categories, which can be seen in Table 2 (Akbar, 2022).

**Table 2.** Likert Scale Response

| Scale Range | Categories |
|---|---|
| 81.26< AB ≤ 100 | Excellent (AB) |
| 62.6< B ≤ 81.25 | Good (B) |
| 43.76< C ≤ 62.5 | Simply (C) |
| <43.75 | Less (K) |

Then, data analysis was carried out to see the effectiveness of the digital comic. To determine effectiveness of the digital comic was tested using a posttest and pretest consisting of 10 essay questions, which include 7 indicators at the cognitive level to determine the increase in students' learning outcomes. The normalized N-gain formula is used in this research, which can be seen below.

$$N - gain = \frac{Postest\ score - Pretest\ Score}{Maximal\ Score - \ Pretest\ Score}$$

After that, data analysis will be carried out using the N-gain value category in Table 3 (Sukarelawan, 2024).

**Table 3.** N-Gain Formula Value Range

| Scale Range | Categories |
|---|---|
| 0.7 ≤ g ≤ 100 | High |
| 0.30 ≤ g < 0.70 | Medium |
| 0.00 < g < 0.30 | Low |
| g = 0.00 | There was no increase |
| -1.00 ≤ g < 0.00 | There was a decline |

DOI: https://doi.org/10.17509/10.17509/aijbe.v8i2.83847
e-ISSN 2621-7260

## RESULTS AND DISCUSSION

The process of implementing research on the development of Tissue Culture digital comic based on mobile learning begins with the analysis stage. At the analysis stage, variables are based on the problem analysis, student characteristics, needs analysis, curriculum analysis, and learning objectives analysis. From the results of this stage, information was obtained that there were no digital comic learning media based on mobile learning that could help understand and could also be used as an effective alternative for elaborating the mini research process. The digital comic design can be seen in Figure 1.

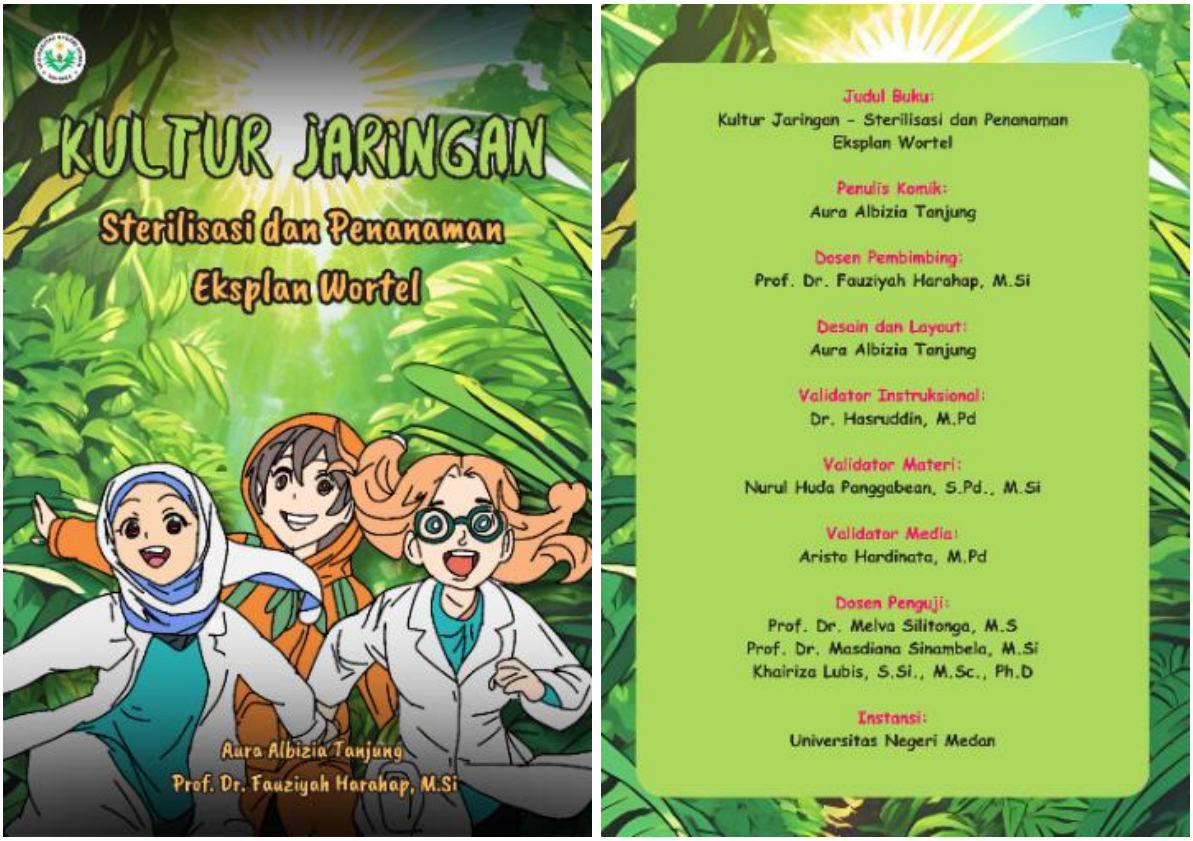


**Figure 1.** Tissue Culture Digital Comic Design

The structure of the draft digital comic consists of 1) Cover, 2) Instruction for Use, 3) Learning Outcomes, 4) Synopsis, 5) Character Introduction, 6) Table of Contents, 7) Chapter I: Basic Concepts of Tissuce Culture, 8) Chapter II: Tissue Culture Requirements, 9) Chapter III: Aseptic Working Techniques, 10) Chapter IV: Sterilization and Planting of Carrot Explants, 11) Glossary, 12) Author Biography, 13) List of Figures, 14) Bibliography, 15) Back cover. This digital comic is compiled based on mobile learning using Google Sites, so that this digital comic can be used both online, when opening the link that will access the website, as in Figure 2. And it can be accessed offline when we download the comic in PDF form.

DOI: https://doi.org/10.17509/10.17509/aijbe.v8i2.83847
e-ISSN 2621-7260


**Figure 2.** Google Site Website Digital Comic

*Feasibility Test According to Instructional Expert*

Based on the assessment of the digital comic learning media based on mobile learning by the instructional expert. The digital comic was assessed in terms of the material suitability, systematic delivery of material, student-centered learning, and digital comic language efficiency in Table 4.

**Table 4.** Instructional Expert Validation

| Assessment Component | Score | Criteria |
|---|---|---|
| Material Suitability | 100 | Very Feasible |
| Systematic Delivery of Material | 91.6 | Very Feasible |
| Student-Centering in Learning | 100 | Very Feasible |
| Digital Comic Language Efficiency | 83.3 | Very Feasible |
| **Average** | 93.75 | Very Feasible |

From the aspect of material suitability, the digital comic is categorized as feasible with a percentage of 100 in the "very feasible" category, this means that the digital comic developed has a scope of material that is in accordance with the CPMK (Course Learning Outcomes) in the Semester Learning Plan (RPS) based on the curriculum. From the aspect of systematic delivery of material, the digital comic is categorized as feasible with a percentage of 91.6 in the "very feasible" This means that the method of delivering the material helps students to understand the learning process clearly and logically. From the aspect of student-centered learning, the digital comic is categorized as feasible with a percentage of 100 in the "very feasible" This means the digital comic encourages students to be more active, provides opportunities for independent exploration, and meets various learning styles. From the aspect of digital comic language efficiency, the digital comic is categorized as feasible with a percentage of 83.3 in the "very feasible" This means the digital comic learning media, which includes sentence structure, spelling, terminology, and grammar accordance with PUEBI (General Guidelines for Indonesian Spelling). The efficiency of language used in digital comics has a significant impact on the effectiveness and comprehension of students' reading, where the use of concise and clear language increases effectiveness in the learning process (Nurdin et al., 2023).

Based on the results of the validation of instructional experts, the digital comic learning media received a validity percentage value of 93.75. If adjusted to the table above, the percentage value is included in the interval of 81.26% - 100%, so that the digital comic learning media in terms of presentation material is very feasible and valid to use.

DOI: https://doi.org/10.17509/10.17509/aijbe.v8i2.83847
e-ISSN 2621-7260

*Feasibility Test According to Material Expert*

Based on the assessment of the digital comic learning media based on mobile learning by the material expert. The digital comic was assessed in terms of the suitability of the content material, mobile learning, and presentation eligibility in Table 5.

**Table 5.** Material Expert Validation

| Assessment Component | Score | Criteria |
|---|---|---|
| Suitability of The Content Material | 81.25 | Feasible |
| Mobile Learning | 87.5 | Very Feasible |
| Presentation Eligibility | 85 | Very Feasible |
| **Average** | 84.5 | Very Feasible |

In terms of the suitability of the content material indicator, this digital comic is categorized as very feasible with a score of 81.25. This shows that the digital comic developed are "feasible" in terms of material suitability. One important element in digital comics is validity, which is part of content validity: the book has been compiled based on solid theory and logic (Harahap et al., 2024). In terms of mobile learning, this digital comic is categorized as "very feasible" with a score of 87.5. This shows that the developed digital comic is feasible. Digital comics offer a learning experience that can be accessed flexibly and also on mobile. Mobile learning media is used effectively in the learning process (Khoiri et al., 2024; Tarigan et al., 2021). In terms of presentation eligibility, this digital comic is categorized as "very feasible" with a score of 85. This shows that the developed digital comics are feasible. Teaching materials can be taught well if presented in clear and easy-to-understand language, delivered in an interesting way, and equipped with pictures and explanations (Dewi & Nugrahaningsih, 2021).

Based on the results of the validation of material experts, the digital comic learning media received a validity percentage value of 84.5. If adjusted to the table above, the percentage value is included in the interval of 81.26% - 100%, so that the digital comic learning media in terms of presentation material is very feasible and valid to use.

*Feasibility Test According to Media Expert*

Based on the assessment of the digital comic learning media based on mobile learning by the media expert. The digital comic was assessed in terms of the suitability of the content material, mobile learning, and presentation eligibility in Table 6.

**Table 6.** Media Expert Validation

| Assessment Component | Score | Criteria |
|---|---|---|
| Media Display | 94.4 | Very Feasible |
| Language, Writing, and Presentation | 96.4 | Very Feasible |
| **Average** | 95.4 | Very Feasible |

From the aspect of media display, the digital comic is categorized as feasible, with a percentage of 94.4 in the "very feasible" category. This shows that digital comics have a design that attracts readers' attention, the arrangement of the front and back covers is appropriate, the selection of the right type and size of font, elements such as comparable icons and images, illustrations that describe the content well, and a combination of colors that are pleasing to the eye (Hidayati & Christanti, 2024). From the aspect of language, writing, and presentation, the digital comic is categorized as feasible, with a percentage of 96.4 in the "very feasible" category. This shows that one of the important factors in making textbooks is the readability of the subject matter, where the layout of sentences, the use of words, and phrases affect the content of the textbook; a planned and effective language system and sentence structure produce quality textbooks (Zamilah et al., 2024).

DOI: https://doi.org/10.17509/10.17509/aijbe.v8i2.83847
e-ISSN 2621-7260

Based on the results of the validation of media experts, the digital comic learning media received a validity percentage value of 95.4. If adjusted to the table above, the percentage value is included in the interval of 81.26% - 100%, so that the digital comic learning media in terms of presentation material is very feasible and valid to use.

*Tissue Culture Lecturer Responses to The Digital Comic*

The assessment aspect of tissue culture response consists of the aspect of the digital comic display, language, eligibility of digital comic content, and use of digital comic media, which can be seen in Table 7.

**Table 7.** Culture Tissue Lecturer Response

| Assessment Component | Score | Criteria |
|---|---|---|
| Digital Comic Display | 87.5 | Excellent |
| Digital Comic Language | 75 | Good |
| Eligibility of Digital Comic Content | 82 | Excellent |
| Use of Digital Comic Media | 75 | Good |
| **Average** | 79.9 | Good |

Based on the results of the response to the digital comic by the tissue culture lecturer, an average rating of 79.9% was obtained with good criteria. The results of this response show that in terms of the appearance of digital comics, a learning resource for students in the learning activities of network culture courses.

*Field Trial of Student Responses*

At this stage, a response field test was carried out on students, carried out by individual tests on 3 students, small group tests on 10 students, and limited group tests on 20 students. This trial consists of 3 aspects, namely: digital comic display, presentation of digital comic media, and use of digital comic media. A comparison of the average percentage of student responses to individual tests, small group tests, and limited group tests can be seen in Figure 3.

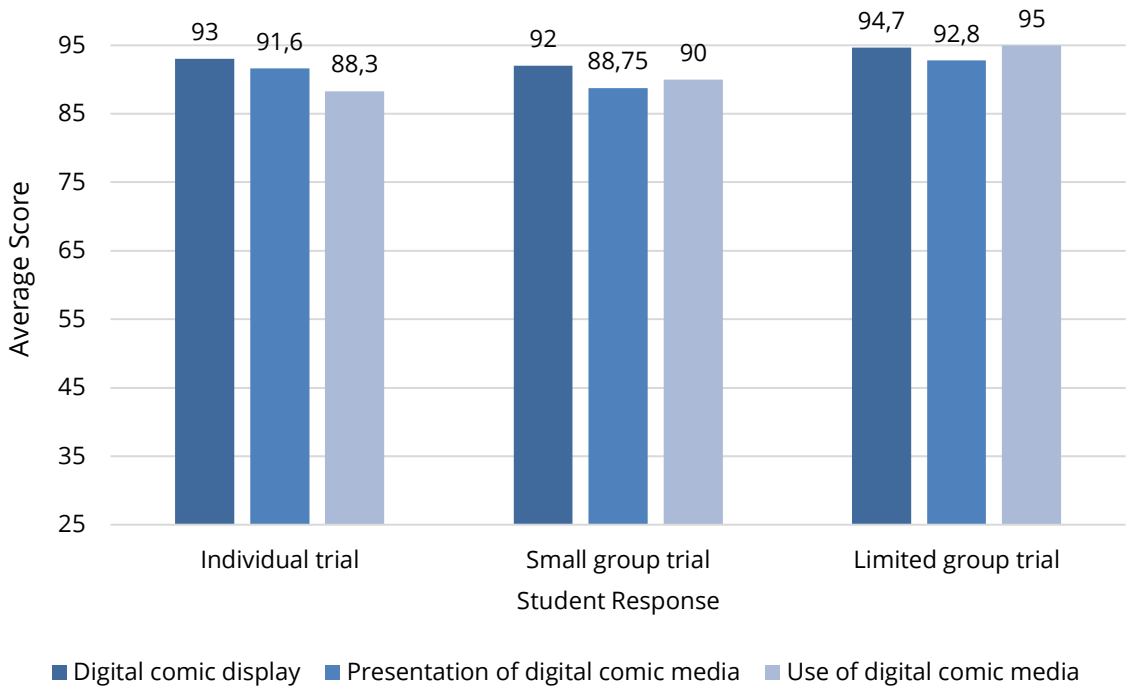


**Figure 3.** Average Field Trial of Student Response

DOI: https://doi.org/10.17509/10.17509/aijbe.v8i2.83847
e-ISSN 2621-7260

The field trial in an individual group consisting of 10 students obtained a score of 91, with a very interesting category. Meanwhile, from small group consisting of 10 students obtained an average score of 90.2, with a very interesting category, and a limited group consisting of 20 students obtained an average score of 94.2, with a very interesting category.

*Effectiveness of Tissue Culture Digital Comic Based on Mobile Learning*

The N-gain test aims to determine the effectiveness of the digital comic in improving learning outcomes about tissue culture, especially in the basic concepts of tissue culture, tissue culture requirements, aseptic working techniques, sterilization and planting of carrot explants.

**Table 8.** Result of The N-Gain Test

| Score | Amount | Presentation | Criteria |
|---|---|---|---|
| 0.7 < N-Gain ≤ 100 | 12 | 46.15% | High |
| 0.30 ≤ N-Gain ≤ 0.70 | 14 | 53.84% | Medium |
| 0.00 < N-Gain < 0.30 | 0 | 0% | Low |

Based on the results of the calculation of the N-Gain test, it shows that most students have an average N-Gain score of 0.7 < N-Gain ≤ 100, which is as many as 9 people, then the average N-Gain value for the PSPB 22 D class is 0.68 or 68% which is in the "medium" category where the category is almost heading towards the "high" category. Based on the N-Gain score, it can be concluded that the digital comic learning media that has been developed is effective enough in improving students' learning outcomes. The use of digital comics can support and attract students' interest, motivate them, and positively influence the improvement of their learning outcomes (Harahap et al., 2024; Khotimah & Hidayat, 2022). During the learning process, there was an increase in students' activity in asking questions about the project to be carried out. The use of learning media combined with teaching materials can activate interest and enthusiasm for learning, encourage and motivate the teaching and learning process, and have a significant influence on the psychological and cognitive aspects of students (Ulviah et al., 2021). This research has a positive impact on the learning process. The use of mobile-based digital comic media has been proven to be able to help students understand the concepts and stages of work in a more interesting and easy-to-understand manner (Nurazreen et al., 2025). Media like this can be an alternative to independent learning solutions outside of lecture hours, especially for students who have difficulty understanding complex scientific texts (Imboy et al., 2025). So that in this case, the digital comic can support hands-on learning that is oriented to direct practice as a support for the mini research process of plant tissue culture courses. According to research from (Tarusu et al., 2024). In the future, the development of similar media can be extended to other topics in the field of biology.

## CONCLUSION

Based on the results of validation by instructional experts, material experts, and media experts, the response of tissue culture lecturers, as well as field trials with individual trials, small group trials, and limited group trials, the digital comic learning media based on mobile learning can be used as a learning resource and implementation in learning for students of the Departemen of Biology, Universitas Negeri Medan.

DOI: https://doi.org/10.17509/10.17509/aijbe.v8i2.83847
e-ISSN 2621-7260

## REFERENCES


Akbar, S. (2022). *Instrumen perangkat pembelajaran*. PT Remaja Rosdakarya Offset.

Amalia, D. R. K., Indrowati, M., & Oetomo, D. (2022). Development of learning media based on e-comic material respiration system to increase learning motivation of high school students. *Proceeding Biology Education Conference, 19*(1), 91–100.

Anggraini, B., & Zulyusri. (2023). Meta-analisis validitas media pembelajaran komik digital pada pembelajaran biologi. *BIODIK: Jurnal Ilmiah Pendidikan Biologi, 9*(4), 111–117. https://doi.org/10.22437/biodik.v9i4.27772

Badeo, J. M. O., & Koc, B. C. U. O. K. (2021). Use of comic-based learning module in physics in enhancing students' achievement and motivation. *Science Education International, 32*(2), 131–136. https://doi.org/10.33828/sei.v32.i2.6

Damanik, M. S. D., & Sipahutar, H. (2022). Development of digital comics as a biology learning media. *Jurnal Pelita Pendidikan, 10*(3), 77–85. https://doi.org/10.24114/jpp.v10i3.34194

Damanik, S. V., Siagian, G., & Pasaribu, S. (2024). Pengembangan media pembelajaran komik digital biologi pada materi sistem pencernaan untuk meningkatkan hasil belajar siswa kelas VIII. *Jurnal Rectum, 5*(3), 444–458. http://dx.doi.org/10.46930/jurnalrectum.v5i3.5036

Damayanti, A. E., & Kuswanto, H. (2021). The effect of the use of indigenous knowledge-based physics comics of android-based marbles games on verba representation and critical thinking abilities in physics teaching. *Journal of Technology and Science Education, 11*(2), 581–593. https://doi.org/10.3926/jotse.1142

Damopolii, I., Lumembang, T., & Ilhan, G. O. (2021). Digital comics in online learning during COVID-19: Its effect on student cognitive learning outcomes. *International Journal of Interactive Mobile Technologies, 15*(19), 33–46. https://doi.org/10.3991/ijim.v15i19.23395

Dewi, L. K., & Nugrahaningsih, W. H. (2021). Development of digital comics as a media for biology learning of environmental change for senior high school students. *Jurnal Biologi Edukasi (JBE), 10*(3), 296–302. https://doi.org/10.15294/jbe.v10i3.47381

Harahap, F., & Saragih, W. (2023). Development of android-based learning media on tool sterilization materials. *Jurnal Biolokus, 6*(1), 12–24. http://dx.doi.org/10.30821/biolokus.v6i1.2115

Harahap, F., Nasution, N. E. A., & Manurung, B. (2019). The effect of blended learning on student's learning achievement and science process skills in plant tissue culture course. *International Journal of Instruction, 12*(1), 521–538. https://doi.org/10.29333/iji.2019.12134a

Harahap, S., Harahap, F., Hasanah, D., Sembiring, G. A., Panggabean, S. K. F., Nadhilla, A., Suriani, C., Edi, S., & Daulae, A. H. (2024). Development of tissue culture textbook based on project based-learning to improve science process skills of biology department students Universitas Negeri Medan. *Bioscientist: Jurnal Ilmiah Biologi, 12*(2), 2302–2316. https://doi.org/10.33394/bioscientist.v12i2.13786

Hidayat, N. R., Roemintoyo, & Sutimin, L. A. (2024). Digital comic for differentiated learning: A strategy to enhance elementary reading skills. *Jurnal Teknologi Pendidikan, 26*(3), 843–859. http://dx.doi.org/10.21009/JTP2001.6

Hidayati, K., & Christanti, A. (2024). Developing Medibang Paint-based digital comic for teaching narrative text. *Nusantara Educational Review, 2*(1), 33–42. https://doi.org/10.55732/ner.v1i2.1176

Imboy, D. H. E., Salic, M. A., Bagaloyos, J., Bazer, S. C., & Malayao, S. O. (2025). Development of digital interactive comics for grade 8 learners in cell division. *RSIIS: Research and Scientific Innovative Society*, 1063–1074. https://doi.org/10.47772/IJRISS.2025.9010088

Khoiri, N., Lilyani, F. S. T., & Wijayanto, W. (2024). E-comic as a media to build an understanding of Newton's concepts. *Momentum: Physics Education Journal, 8*(1), 154–165. https://doi.org/10.21067/mpej.v8i1.8478


DOI: https://doi.org/10.17509/10.17509/aijbe.v8i2.83847
e-ISSN 2621-7260

Khotimah, H., & Hidayat, N. (2022). Interactive digital comic teaching materials to increase student engagement and learning outcomes. *International Journal of Elementary Education, 6*(2), 245–258. https://doi.org/10.23887/ijee.v6i2.46038

Nurazreen, M. G., Suriani, A. B., Lilia, E. M., Aliya, N., Azzam, M. B., Adli, M., & Muhammad, D. (2025). Learning using comics and artificial intelligence in physics subjects: A review. *EDUCATUM: Journal of Science, Mathematics and Technology, 12*, 134–147.

Nurdin, Rais, R., Sumadyo, B., & Diharjo, D. (2023). The influence of the use of learning media and learning motivation on social science learning outcomes. *Journal of Educational Research and Evaluation, 7*(4), 629–635. https://doi.org/10.23887/jere.v7i4.66661

Nurinayati, F., Sartono, N., & Evriyani, D. (2018). Development of digital comic as learning media on immune system topic in SMAN 13 Jakarta. *Biosfer, 7*(2), 47–52. https://doi.org/10.21009/biosferjpb.7-2.8

Raneza, F., Widowati, H., & Santoso, H. (2022). Pengembangan komik digital dengan mengintegrasikan nilai-nilai keislaman sebagai media pembelajaran pada materi pokok ruang lingkup biologi. *Bioedusiana: Jurnal Pendidikan Biologi, 7*(1), 60–79. https://doi.org/10.37058/bioed.v7i1.3168

Rifai, A., Sulton, & Sulthoni. (2020). Pengembangan media mobile learning sebagai pendukung sumber belajar biologi siswa SMA. *JKTP: Jurnal Kajian Teknologi Pendidikan, 3*(1), 10–17. http://dx.doi.org/10.17977/um038v3i12019p010

Rofiqoh, D. A., & Kiptiyah, S. M. (2024). Ethnoscience-based digital comic on plant material for grade IV elementary school students. *Mimbar PGSD Undiksha, 12*(1), 163–174. https://doi.org/10.23887/jjpgsd.v12i1.72757

Simatupang, E. C., Silitonga, M., & Rajagukguk, S. H. (2023). Students' critical thinking skills on human respiratory system material in flipped classroom. *Jurnal Pendidikan Biologi Indonesia, 9*(3), 387–393. https://doi.org/10.22219/jpbi.v9i3.26841

Sukarelawan, M. I., Indratno, T. K., & Ayu, S. M. (2024). N-Gain vs stacking. Penerbit Suryacahya.

Syahriani, & Sofyan. (2020). Pengembangan bahan ajar berbasis komik materi Pteridophyta pada mahasiswa Pendidikan Biologi UIN Alauddin Makassar. *BIODIK: Jurnal Ilmiah Pendidikan Biologi, 6*(2), 118–132. https://doi.org/10.22437/bio.v6i2.8855

Tarigan, W. P. L., Sipahutar, H., & Harahap, F. (2021). The effect of interactive digital learning module on student's learning activity and autonomy. *BIOEDUKASI: Jurnal Pendidikan Biologi, 14*(2), 196–208. https://doi.org/10.20961/bioedukasi-uns.v14i2.49366

Tarusu, D., & Wongkar, N. V. (2024). Pemanfaatan media visual untuk meningkatkan hasil belajar siswa kelas V pada mata pelajaran IPAS di SD Inpres Leleko. *Journal on Education, 7*(1), 8387–8395. http://dx.doi.org/10.31004/joe.v7i1.7672

Ulviah, L., Subroto, S. H., & Satifah, O. (2021). Development of comic learning media to improve student's concept understanding and learning independence. *Jurnal Ilmiah PGMI, 7*(1), 29–40. http://dx.doi.org/10.19109/jip.v7i1.8090

Utariyanti, I. F. Z., Wahyuni, S., & Zaenab, S. (2015). Pengembangan media pembelajaran berbasis komik dalam materi sistem pernapasan pada siswa kelas VIII MTs Muhammadiyah 1 Malang. *Jurnal Pendidikan Biologi Indonesia, 1*(3), 343–355. https://doi.org/10.22219/jpbi.v1i3.2668

Wijaya, S. N., Johari, A., & Wicaksana, E. J. (2020). Pengembangan media pembelajaran komik digital berbasis karakter hero Indonesia pada materi sistem peredaran darah. *Didaktika Biologi: Jurnal Penelitian Pendidikan Biologi, 4*(2), 67–78. https://doi.org/10.32502/dikbio.v4i2.2582

Zamilah, Djulia, E., & Lubis, K. (2024). Pengembangan lembar kerja interaktif berbasis literasi sains untuk melatih kemampuan berpikir kritis peserta didik materi fotosintesis. *Jurnal Karya Ilmiah Guru, 9*(1), 294–304. https://doi.org/10.51169/ideguru.v9i1.821

## Acknowledgment

Researcher would like to thank the university which funded this research and the participants who were involved in this research.

## Authors' Note

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

## How to Cite this Article

Tanjung, A. A., Harahap, F., Khalisyah, Z., Anwar, S., Nazwari, A., Pasaribu, F., Sitompul, N. Z., & Sitompul. N. Z. (2025). Development of digital comic learning media based on mobile learning on sterilization and explant planting materials in plant tissue culture courses. *Assimilation: Indonesian Journal of Biology Education, 8*(2), 205-216. https://doi.org/10.17509/10.17509/aijbe.v8i2.83847

DOI: https://doi.org/10.17509/10.17509/aijbe.v8i2.83847
e-ISSN 2621-7260