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Development of digital comics SIPROMAN to improve students' critical thinking and creative thinking skills

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Abstract: This study investigates the effectiveness of siproman digital comics as a learning medium to enhance critical and creative thinking skills in biology, specifically on the human reproductive system. Recognizing the importance of these skills in the 21st century and their current low levels among students, this research employed Educational Design Research (EDR) adapted from the Hannafin & Peck model. Data collection involved questionnaires, student needs analysis, and teacher interviews. Siproman comics were created using Autodesk-SketchBook and underwent feasibility testing by media and material experts, achieving average scores of 85% and 87%, indicating high feasibility. Product trials were conducted with teachers, small (12 students) and large (35 students) groups. A control group pre-test-post-test design, using instruments measuring eight critical thinking and six creative thinking skills, assessed effectiveness. Mancova testing revealed a significant difference ($p<0.001$) between groups across all criteria (Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root). These findings demonstrate that siproman digital comics are effective in improving students' critical and creative thinking skills.

Keywords: critical thinking; creative thinking skills; digital comics siproman

Introduction

The US-based Partnership for 21st Century Skills (P21) states that critical thinking skills are one of the skills needed in the 21st century. This skill is important in developing education in Indonesia which is increasingly complex. Critical thinking skills are skills that include the ability to access, analyze, and synthesize information obtained to be learned, practiced, and mastered (Redecker et al., 2011; Supriyati et al., 2018). In everyday life, critical thinking skills can help someone to distinguish between true and false information, and to make the right decisions in various situations.

The Programme for International Student Assessment (PISA) 2022 shows that the ability of Indonesian students is 36.7% who reach level 2 or more in three main domains: reading, mathematics, and science. Level 2 indicates that students can understand and interpret complex information, and solve problems that only require a few steps. Although there is no specific domain for critical thinking skills, critical thinking skills are integrated into all PISA domains. The PISA 2022 percentage for Indonesia is lower than the average international standard of 81 OECD countries, which is 73.7%. In addition, in the Trends in International Mathematics and Science Study (TIMSS) 2019, the critical thinking skills of Indonesian students in science are ranked 42nd out of 58 countries. The results of the study, by Azrai et al., (2020) also support the data, namely 59% of high schools in East Jakarta have low critical thinking skills with an average score of 4. Low critical thinking skills cause students to experience difficulties when faced with concrete problems in everyday life (Wardatun et al., 2013). Therefore, the application of critical thinking skills in schools is needed.

In addition to critical thinking skills, there are creative thinking skills that need to be developed by students. Creative thinking skills are skills to generate new ideas and innovative solutions. Guilford, (1950) said that creative thinking is a person's skill to generate ideas by thinking divergently. Divergent thinking produces many ideas, perspectives, or solutions to a problem (Dardiri et al., 2020). The Global Creativity Index (GCI) 2022 by the Martin Prosperity Institute shows that Indonesia is ranked 62 out of

132 countries in terms of creative thinking skills. The Progress in International Reading Literacy Study (PIRLS) 2021 measures Indonesia's creative thinking skills, which are ranked 54 out of 61 countries. Trends in International Mathematics and Science Study (TIMSS) 2019, Indonesia is ranked 67 out of 78 countries in terms of creative thinking skills. This means that Indonesia is still lagging behind many other countries in terms of creative thinking skills, which can hinder economic growth and development in Indonesia. Therefore, it is necessary to have learning by improving students' creative thinking skills.

Critical thinking and creative thinking skills are two important skills that are interrelated or complementary. These skills are not formed suddenly but need to be trained. Teachers are obliged to help students practice these skills, so efforts are needed by teachers to improve students' understanding in facilitating the learning process, one of which is by using learning media. Well-designed learning media will greatly help students digest the theories and concepts of the topics presented by the teacher so that they can achieve maximum learning outcomes (Utari et al., 2014).

Learning media can generally be grouped into three types, namely visual media, audio media, and audio-visual media. Visual media is media that has elements in the form of images that can be seen, for example, models, actual objects, charts, maps, comics, flashcards, flannel boards, bulletin boards, whiteboards, slides, and overhead projectors (Dinata, 2013). Audio media is media that is in the form of audio (can only be heard) so that it can stimulate the thoughts, feelings, and attention of students to study the teaching materials. Types of audio media include audio cassettes, radio programs, and audio CDs. Audio-visual media is a combination of visual and audio media, for example, educational television programs and interactive CDs. Comics are a form of visual communication media that has the power to convey information in a popular and easy-to-understand way. This is possible because comics combine the power of images and writing, which are arranged in a picture storyline making information easier to absorb. Generally, there are two types of comics known to the public, namely printed comics and digital comics. Printed comics are usually in book form while digital comics are comics that are read using electronic media such as computers and gadgets. Printed comics have the disadvantage that they are relatively expensive and easily damaged. Meanwhile, digital comics are durable and easily accessible, so digital comics are increasingly in demand by the public (Nurinayati et al., 2018).

Comics can be used as a pedagogical tool (teaching and learning). Comics in the field of education are very developed and continue to grow at all levels, from elementary school to university-level teaching. Comics as a visual teaching aid help someone to enjoy reading more (Svatoš & Manĕnová, 2017). The role of comics in education is increasingly being considered in the learning process because it is considered more effective, can increase interest in learning, and is a medium that supports curriculum implementation (Fatimah & Widiyatmoko, 2014). In addition, comics can specifically be used as a science communication tool very well in interestingly conveying scientific concepts (Tatalovic, 2009). For example, comics are used to teach laboratory safety and ethics (eg Archie comics: Archie and Friends "The Battle of Toxic Household Waste" and Let's Have a Blast) (Szafran et al., 1994).

As part of science, Biology is a science that studies living things with their various complexities. Among the Biology materials studied in class XI natural science, the reproductive system material is considered quite difficult for students to understand because the material is related to understanding internal organs, organ systems, and mechanisms that occur in body organs. In their research, Tenzer et al., (2022) stated that many students had difficulty in the concept of gamete formation, ovulation, menstruation, fertilization, gestation, childbirth, and lactation, with the highest percentage of difficulty in the concept of menstruation. This is also supported by a literature review conducted by Laksmi et al., (2022) namely that an understanding is needed to analyze a problem in the reproductive system material, including problems regarding puberty, anatomy, concepts of the reproductive system, and health problems. Based on the results of the needs questionnaire and student interviews using the survey method of 53 class XII natural science students at Muhammadiyah 4 Senior High School Jakarta, data on topics that were considered difficult were 71.7% on reproductive system concepts and 41.5% on anatomical structures. The results of interviews with Biology teachers showed that the reproductive system material that was less understood was in the puberty sub-material. Learning about the human reproductive system requires comfort and safety, especially when explaining the anatomy because students tend to feel embarrassed if they have to ask or search for the vocabulary individually.

The use of comics as a medium can be used to teach Biology learning materials about the reproductive system. Stated that this material requires special understanding because several material concepts cannot be seen directly by the eye so that visual media can be used in the form of digital comics in comic strip format (Setiawan & Setyowati, 2021; Putri & Ristiono, 2021; and Deadara et al., 2017). Comic strips are a series of images arranged in panels and interconnected to form a narrative, series, with text in balloons and captions. Learning using comics becomes more fun, and interesting, and can increase analytical and creative activity in the brain. In addition, comics can be used independently, can be carried anytime and anywhere by students, and can be used by teachers to support Biology learning (Ahmat & Sukartiningsih, 2013).

Method

Research Design

The method used in this study is a research and development method that refers to the formulation of Hannafin and Peck, (1988). This research and development are divided into several stages. The steps involved include (1) analysis, (2) design, (3) development/implementation, (4) evaluation and revision.

Research Subjects

Particular science students of class XI Natural Science at Muhammadiyah 4 Senior High School Jakarta were surveyed. The distribution of student needs analysis questionnaires was conducted with class XII Natural Science students, who had already received reproductive system material, along with interviews with Biology teachers from Muhammadiyah 4 Senior High School Jakarta regarding learning media. Small group tests involved a sample of 12 students, while large group tests involved 35 class XI Natural Science students. The effectiveness test was carried out with 64 class XI Natural Science students from Muhammadiyah 4 Senior High School Jakarta.

Instruments

The instruments used in this study were a needs analysis questionnaire (biology students and teachers), product validation questionnaires (media experts and material experts), product assessment questionnaires (biology teachers, small groups, and large groups), and evaluation questions (pre-test and post-test) conducted via Google form. A needs analysis questionnaire (biology students and teachers) was used to obtain initial data and supporting data to see problems in learning reproductive system material. Product validation questionnaires by validators (media experts and material experts) were used to test the initial product validation. Product assessment questionnaire (Biology teachers, small groups, large groups) to determine the responses of teachers and students to learning media on bacteria material. The evaluation test used pre-test and post-test question instruments consisting of 8 critical thinking skills questions and 6 creative thinking skills.

Procedure

The initial stage of the study was data collection by distributing questionnaires and interviews. The questionnaire was distributed to students of class XI natural science to analyze students' needs regarding aspects of Biology learning, utilization of learning media, and utilization of gadgets and digital comics. At the interview stage, several questions were asked to the Biology teacher of class XI natural science regarding Biology learning, utilization of media, and learning support facilities. Furthermore, analyzing Biology learning materials and creating product designs that will be developed as learning media. The next stage is to carry out the product validation test stage. The calculation of product validation is broken down using references according to the criteria in the descriptive criteria for the percentage of product validation adjusted from Utomo, et al., (2020). The product validation test was carried out by validators, namely media experts and material experts. The product trial stage was carried out by students (small and big groups) and Biology teachers of class XI natural science Muhammadiyah 4 Senior High School Jakarta. At this stage, the teacher provided feedback on the learning media on the human reproductive system material. The trial to the teacher was carried out because the teacher was the user who would teach with the media. A small group trial using a sample of 12 students, to find out the opinions, assessments, and suggestions from students regarding the product. The results obtained in the small group test were used for product revision. After the revision, a large group trial was conducted using a sample of 35 students. At this stage, product refinement was also carried out. The effectiveness test was conducted on 64 students using a random sampling technique. The product effectiveness test was conducted to measure the results of the pre-test and post-test scores for critical thinking skills and creative thinking skills. Measurement of the instrument for the results of critical thinking skills and creative thinking skills on the human reproductive system material was carried out by conducting validity and reliability tests. The validity test of the research instrument used the Pearson product-moment correlation formula. The reliability test used the Kuder-Richardson 21 (KR-21) formula. The effectiveness test used a pre-test-post-test control group research design (32 students in class control and class experiment).

Data Analysis

This study used data analysis techniques, including prerequisite, hypothesis, and n-gain tests. The steps taken in data analysis techniques. This condition test is very important to ensure that the data meets the assumptions underlying MANCOVA (Multivariate Analysis of Covariance). If these assumptions are violated, MANCOVA results may be invalid or unreliable.

The normality test conducted consists of univariate and multivariate normality test stages. The univariate normality test checks whether one variable is normally distributed. The univariate normality test uses the

Shapiro-Wilk test, the Kolmogorov-Smirnov test, and the Anderson-Darling test, with a significance level (α) of 0.05. Data can be said to be normally distributed if the significance value (p) is greater than α and the data is said to be not normally distributed if the opposite applies. The results of the univariate normality test can provide an initial indication that the data may be normally distributed. However, for a stronger conclusion, further analysis can be carried out using the multivariate normality test. The multivariate normality test is used to check whether a group of variables is normally distributed together. This multivariate normality test is very important because it is included in the basic assumptions of MANCOVA. The multivariate normality test uses the Mardia Test and the Henze-Zirkler Test with a significance level (α) of 0.05. Data can be said to be normally distributed if the significance value (p) is greater than α and data can be said to be not normally distributed if the opposite is true.

The homogeneity test of this study consists of two stages, namely the homogeneity test of variance and the covariance matrix. The homogeneity test of variance is carried out to determine whether the distribution of the data obtained is homogeneous or not. In this test, Levene's test and Bartlett's test are used. The data obtained is said to be homogeneous if the significance value (p) is greater than α = 0.05 and the data is said to be inhomogeneous if the opposite applies. The homogeneity test of the covariance matrix is conducted using the Box's M test. The Box's M test is one of the assumption tests in multivariate variance analysis (MANCOVA). The Box's M test is carried out to test the equality of variance-covariance in both dependent variables together. The testing criteria for the Box's M test are homogeneous data if the significance value (p) is greater than (α) 0.05 and the data is not homogeneous if the opposite applies.

Before MANCOVA analysis was conducted, multicollinearity between covariates (pre-test critical thinking skills and pre-test creative thinking skills) was checked through a correlation matrix and VIF (Variance Inflation Factor). If the correlation between covariates is not too high (below 0.9), it is usually not necessary to report other statistics such as VIF (Variance Inflation Factor). VIF above 10 is considered an indication of significant multicollinearity.

Univariate Outliers: Checked with a boxplot. Pay attention to the points outside the "whisker" on the box plot. Outliers are marked with a small circle (o) or star (*) outside the "whisker" boxplot. Circles usually represent outliers, while stars represent extreme outliers. Multivariate Outliers: Checked by calculating the Mahalanobis Distance and comparing it to the critical Chi-Square value.

There must be a linear relationship between each pair of dependent variables and each group of independent variables. This is checked by creating a scatterplot matrix for each group. If the points on the scatterplot form a straight-line pattern, then the relationship is linear. If the points form a curved pattern or other non-linear pattern, then the assumption of linearity is met.

In this study, hypothesis testing was conducted using the MANCOVA test. The MANCOVA test is a statistical technique that is useful for testing differences between experimental and control groups on a combination of dependent variables, after controlling for the effects of covariates. The following are the hypotheses proposed in the MANCOVA test:

H0: There is no multivariate difference between the control and experimental groups on the combination of dependent variables (post-test critical thinking skills and post-test creative thinking skills), after controlling for the effects of covariates (pre-test critical thinking skills and pre-test creative thinking skills).

H1: There is a multivariate difference between the control and experimental groups on the combination of dependent variables (post-test critical thinking skills and post-test creative thinking skills), after controlling for the effects of covariates (pre-test critical thinking skills and pre-test creative thinking skills).

The MANCOVA test criteria can be done by comparing the Sig. values of Pillai's Trace, Wlks' Lambda, Hotelling's Trace, or Roy's Largest Root to the level of significance. If the Sig value is greater than (α) 0.05 then H0 is accepted and vice versa.

Results and Discussion

This research produces a biology learning media product in the form of a digital comic SIPROMAN (Human reproduction system) on the human reproductive system material for class XI natural science students of Muhammadiyah 4 Senior High School Jakarta. The product development procedure is adapted from the Hannafin and Peck model, (1988) with stages (1) analysis, (2) design, (3) development/implementation, and (4) evaluation and revision.

Analysis
Student Analysis
Based on the results of the data obtained in Table 1, the topics that were difficult for students to understand were 71.7% of the concepts of the Human Reproductive System, namely the process of sperm formation (spermatogenesis), the process of egg cell formation (oogenesis), menstruation and 41.5% regarding anatomical structures. Factors that cause students to experience difficulties in the material on the human reproductive system include hormones involved in spermatogenesis, oogenesis, and menstruation, and understanding anatomical structures that are considered quite complex because

there are so many things to memorize and understand. The many diseases in the Human Reproductive System make students confused, and understanding puberty is often an obstacle because students are embarrassed to ask questions during learning. The results of the analysis of student needs also show that the Biology learning media that are often used in schools for the Human Reproductive System material are PowerPoint and teaching aids (Table 2). Meanwhile, comic learning is 15.1%, which shows that comics as a learning medium are still less popular for human reproductive system material.

Table 1. Difficult Topics in Human Reproductive System Material.

No.	Aspects of Reproductive System Material	Percentage (%)
1	Puberty (Secondary Characteristics)	11.3
2	Concepts of Sperm/Ovum Formation & Menstruation	71.7
3	Anatomy Structure	41.5
4	Reproductive Health Problems	13.2

Table 2. Biology Learning Media Used by Students in Schools for Human Reproductive System Material.

No.	Learning Media	Percentage (%)
1	PowerPoint	77.4
2	Teaching Aids	56.6
3	Android Apps	28.3
4	Learning Comics	15.1

Educator Needs Analysis

The results of interviews with Biology teachers showed that the material on the Human Reproductive System that was poorly understood was in the sub-material on Human Reproductive Organ Anatomy and puberty, especially on menstruation. Both teacher interviews and student needs analysis equally highlighted difficulties in the sub-material on reproductive organ anatomy and menstruation or understanding the process of mechanisms in the reproductive system. This indicates the existence of cross-validation which strengthens the findings that these two areas are indeed challenges for students. The opinions of Biology teachers regarding the difficulties in learning about the human reproductive system that are often experienced by students are understanding the function of reproductive system organs, understanding the function of hormones during menstruation and students tend to feel embarrassed if they have to ask individually about menstruation problems. The results of the interviews showed that the media used in learning are usually PowerPoint, e-books, and learning videos. According to Biology teachers, learning media is very much needed for visualizing the material on the Human Reproductive System. Teachers also support innovation in the development of media in the form of digital comics as a learning medium, because digital comics can offer a different and more interesting approach to explaining difficult-to-understand material easier and more effectively by creating digital comics based on activities in the surrounding environment. In addition, the availability of the Internet in schools supports the use of digital media, including digital comics. This facilitates student access to learning materials inside and outside the classroom.

Design

Design is made by designing a clear and detailed product framework containing visual appearance, materials, and content to be developed (Figure 1). Digital comics are published on the Webtoon platform. The Webtoon platform can be accessed via the web or applications available on the Play Store and App Store via mobile (Android and iOS). The platform was chosen because it can be used for free and paid so that it is easily accessible by teachers and students.
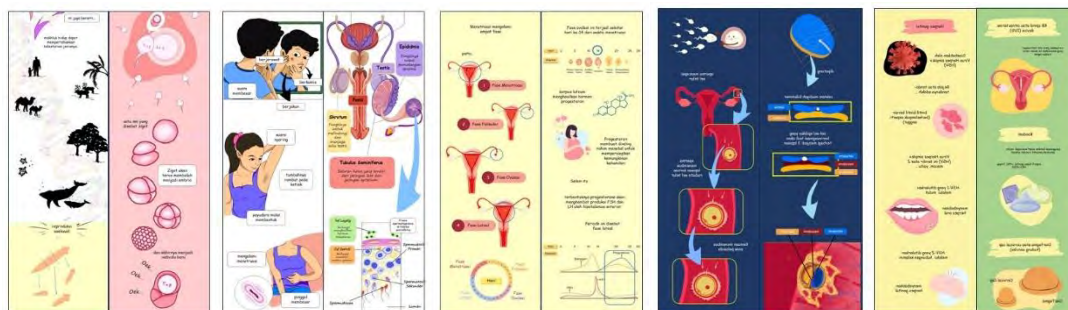

Figure 1. Sub Chapter View of Reproductive System Material

Development/implementation

The product feasibility test stage is still included in the Development/implementation stage. The feasibility test was carried out by several experts such as material experts and media experts.

Test media suitability

Four media experts conducted the feasibility test of the digital comic media SIPROMAN. The experts assessed the product and then completed the media feasibility test instrument on Google Forms. Four aspects were tested: text, image, story, and display. The results of the percentage calculation of each element in the media feasibility test can be seen in Table 3.

Table 3. Results of Percentage Calculation of Each Aspect in Media Feasibility Test

Media Expert	Percentage Obtained Media Feasibility Test Aspect				Average
	Text	Image	Story	Display	
1	81%	88%	75%	92%	84%
2	88%	88%	100%	92%	92%
3	75%	75%	75%	75%	75%
4	100%	88%	88%	83%	90%
Average	86%	84%	84%	85%	85%

Based on the percentage obtained, the average of each aspect in the media feasibility test is 85% with the interpretation of the overall product feasibility test score, namely very feasible, can be used without revision. The criteria for interpreting the product feasibility test score are adapted from (Utomo et al., 2020).

Material Suitability Test

The feasibility test of the SIPROMAN digital comic material was conducted by 4 material experts. The material experts assessed the product and then completed the material feasibility test instrument on Google Forms. There are two aspects to the material feasibility test, namely: the material aspect and the learning aspect. The results of the calculation of the percentage of each element in the material feasibility test can be seen in Table 4.

Table 4. Results of the Percentage Calculation of Each Aspect in the Material Feasibility Test

Material experts	Media Experts Percentage Aspect of Material Feasibility Test Average		Average
	Material (Content)	Teaching	
1	93%	100%	96%
2	86%	88%	87%
3	86%	88%	87%
4	79%	75%	77%
Average	86%	88%	87%

Based on the percentage of each aspect in the material feasibility test, the score obtained was 87% with the interpretation of the overall product feasibility test score being very feasible and can be used without revision. The product feasibility test score interpretation criteria are adapted from (Utomo et al., 2020). After the feasibility test is completed by several experts such as material experts and media experts, implementation will be carried out. The implementation of the product was carried out on Biology teachers and groups of class XI natural science students referred to as small or large group tests. Group testing is carried out to obtain feedback from users who represent actual users. The number of subjects involved in small group testing was 12 students and large group trials were 35 students.

Biology Teacher Assessment

The teacher assessment stage was carried out by 2 Biology teachers of class XI natural science. This test aims to determine the teacher's response to the digital comic SIPROMAN (Human Reproductive System). At this stage, teachers are asked to use learning media and then fill out the assessment instrument on Google Forms. There are four aspects in the assessment of Biology teachers, namely: material aspects, presentation aspects, language aspects, and benefits aspects. The results of the calculation of the percentage of each aspect in the Biology teacher trial can be seen in Table 5. Based on the percentage obtained by the trial score by the Biology teacher as a whole, namely 87% with a very feasible interpretation, it can be used without revision. The interpretation criteria for the product feasibility test score were adapted from (Utomo et al., 2020).

Table 5. Results of Percentage Calculation of Each Aspect in the Eligibility Test by Biology Teachers

Biology Teacher	Trial Aspect by Teacher				Average
	Material (Content)	Presentation	Language	Benefits	
1	83%	88%	88%	83%	85%
2	92%	83%	100%	75%	88%
Average	88%	86%	94%	79%	87%

Small and Large Group Trials

The group trial stage aims to determine students' responses to the digital comic learning media SIPROMAN (Human Reproductive System). At this stage, students are asked to use the learning media and then fill out the assessment instrument on Google Forms. There are four aspects in the group trial instrument, namely: material aspect, presentation aspect, language aspect, and benefit aspect. The results of the calculation of the percentage of each aspect in the small and large group trial can be seen in Table 6.

Table 6. Results of the calculation of the average percentage of each aspect in the small small and large group trial instrument

Trial	Percentage Value of Trial aspect				Average
	Material (Content)	Presentation	Language	Benefits	
Small Group	95%	94%	93%	93%	94%
Large Group	92%	92%	92%	91%	92%
Average	94%	93%	93%	92%	93%

Based on the percentage obtained, an average score of 93% was obtained with the interpretation of the overall small group trial score, namely very feasible, can be used without revision. The criteria for interpreting the product feasibility test score were adapted from (Utomo et al., 2020).

Evaluation and Revision

This stage aims to assess the effectiveness and efficiency of the product on students. Improvements to the developed product are carried out at each stage.The effectiveness test was conducted on 64 students. The implementation of learning was face-to-face in class. The learning process began with students working on the pre-test questions first, then allowed to learn using digital comic learning media SIPROMAN for the experimental class and PowerPoint for the control class, then a post-test was conducted. The critical thinking skills and creative thinking skills instruments were carried out by distributing questionnaires in a class consisting of 8 critical thinking skills questions and 6 creative thinking skills questions on essay questions. Descriptive Analysis of Pre-Test and Post-Test Scores for Critical Thinking Skills and Creative Thinking Skills can be seen in Tables 7.

Table 7. Descriptive Analysis of Pre-Test and Post-Test Scores

Descriptive Analysis	Critical Thinking Skills			
	(Pre-Test)		(Post-Test)	
	Control	Experimental	Control	Experimental
N	32	32	32	32
Mean	70.3	77.2	80.8	82.4
Std. error mean	1.60	1.31	1.15	1.10
Median	69.0	75.0	81.0	81.0
Standard deviation	9.04	7.42	6.49	6.19
Minimum	56	66	69	72
Maximum	88	91	91	94

Descriptive Analysis	Creative Thinking Skills			
	(Pre-Test)		(Post-Test)	
	Control	Experimental	Control	Experimental
N	32	32	32	32
Mean	54.0	61.4	61.3	68.0
Std. error mean	1.71	1.65	1.72	1.59
Median	54.0	63.0	63.0	67.0
Standard deviation	9.65	9.35	9.71	8.97
Minimum	38	46	46	54
Maximum	71	79	79	83

In the next stage, the score data of critical thinking skills and creative thinking skills in each group were analyzed statistically through the MANCOVA (Multivariate Analysis of Covariance) test. This test was conducted to test the differences between the experimental group and the control group on the combination of dependent variables, after controlling the effects of covariates. The MANCOVA test is conducted by testing the prerequisite test and hypothesis test.

Prerequisite Test
Prerequisite tests are essential to ensure that the data meet the assumptions underlying MANCOVA. If these assumptions are violated, MANCOVA results may not be valid. The following are the main assumptions of MANCOVA.

Normality Test
The normality test conducted consists of univariate and multivariate normality test stages. The univariate normality test is used to check whether one variable is normally distributed.

Table 8. Univariate Normality

| No. | Tests of Normality | Critical Thinking Skills | | | |
| | | Pre-Test (p-value) | | Post-Test (p value) | |
		Control	Experimental	Control	Experimental
1	Shapiro-Wilk	0.220	0.073	0.088	0.103
2	Kolmogorov-Smirnov	0.806	0.347	0.303	0.498
3	Anderson-Darling	0.332	0.061	0.103	0.096
No.	Tests of Normality	Creative Thinking Skills			
		Pre-Test (p-value)		Post-Test (p value)	
		Control	Experimental	Control	Experimental
1	Shapiro-Wilk	0.204	0.261	0.149	0.098
2	Kolmogorov-Smirnov	0.917	0.663	0.896	0.768
3	Anderson-Darling	0.336	0.316	0.253	0.179

Table 8 shows that the data can be said to be normally distributed if the significance value (p) is greater than α (0.05). Shapiro-Wilk, Kolmogorov-Smirnov, and Anderson-Darling show that the data is normally distributed (p > 0.05).

The results of the univariate normality test can provide an initial indication that the data may be normally distributed. However, for a stronger conclusion, further analysis can be carried out using the multivariate normality test. The multivariate normality test checks whether a group of variables is normally distributed together. This multivariate normality test is very important because it is included in the basic assumptions of MANCOVA.

Table 9. Multivariate Normality

No.	Normality Test	Statistical	p-value
1	Mardia's Skewness Test	1.1925340	0.233
	Mardia's Kurtosis Test	-0.8407981	0.400
	Mardia's Test	2.1932147	0.334
2	HZ Test	0.6366576	0.829

Based on Table 9, the data can be said to be multivariate normally distributed if the significance value (p) is greater than α (0.05). The Mardia Test and Henze-Zirkler Test show that the data is multivariate normally distributed (p > 0.05).

Homogeneity Test
The homogeneity test of this study consists of two stages, namely the homogeneity test of variance and the covariance matrix. The homogeneity test of variance is carried out to determine whether the distribution of the data obtained is homogeneous or not. The data in Table 10 is said to be homogeneous if the significance value (p) is greater than α = 0.05. Levene's and Bartlett's indicate that the data is homogeneous (p > 0.05).
The homogeneity test of the covariance matrix was performed using the Box's M test. The Box's M test is one of the basic assumption tests in multivariate analysis of variance (MANCOVA). The Box's M test is performed to test the equality of variance-covariance in both dependent variables simultaneously.

Table 11 shows that (p) 0.937 was obtained. The testing criteria for the Box's M test are homogeneous data if the significance value (p) is greater than (α) 0.05. This means that the assumption of homogeneity of the covariance matrix is met, namely that the data can be said to be homogeneous.

Table 10. Homogeneity of Variance

No.	Homogeneity of Variances Tests	Critical Thinking Skills (p-value)		Creative Thinking Skills (p-value)	
		Pre-Test	Post-Test	Pre-Test	Post-Test
1	Levene's	0.405	0.953	0.995	0.678
2	Bartlett's	0.276	0.800	0.862	0.665

Table 11. Homogeneity of Covariance Matrix (Box's M Test)

χ²(Chi-square)	Df (degree of freedom)	P
0.417	3	0.937

No Multicollinearity

Before the MANCOVA analysis was conducted, multicollinearity between covariates (pre-test critical thinking skills and pre-test creative thinking skills) was checked through the correlation matrix and VIF (Variance Inflation Factor). In Table 12 it was found that the correlation between critical thinking skills (pre-test) and creative thinking skills (pre-test) was 0.743. This value shows a moderate correlation but is still below the threshold of 0.9, indicating that multicollinearity does not occur. The VIF value for both covariates is 1.58. VIF above 10 is considered an indication of significant multicollinearity. The VIF value is far below 10, thus confirming that multicollinearity does not occur.

Table 12. Multicollinearity
Covariate Correlation Matrix

Correlation matrix	Critical Thinking Skills (Pre-Test)	Creative Thinking Skills (Pre-Test)
Critical Thinking Skills (Pre-Test)	1.000	0.743
Creative Thinking Skills (Pre-Test)	0.743	1.000

VIF (Variance Inflation Factor) value

	VIF
Critical Thinking Skills (Pre-Test)	1.583561
Creative Thinking Skills (Pre-Test)	1.583561

No Univariate or Multivariate Outliers

An important assumption in MANCOVA is the absence of outliers that can affect the validity of the analysis results. Therefore, univariate and multivariate outliers are checked before testing MANCOVA. Outliers in MANCOVA testing can pull the average in the wrong direction. Outliers, both univariate and multivariate, can significantly affect the results of the analysis by distorting estimates of means and covariances. In relationships between data, outliers can make relationships that do not exist appear to exist.

Univariate outliers are examined with a boxplot. Note the points outside the "whisker" in the boxplot. Outliers are marked with small circles (o) or stars (*) outside the boxplot "whisker". Circles usually represent outliers, while stars represent extreme outliers. In Figures 2 and Figures 3 there are no outliers, no points outside the "whisker" on the boxplot and it is known that the class descriptions are control (1) and experiment (2).

Univariate multivariate outliers are examined by calculating the Mahalanobis Distance and comparing it with the Chi-Square critical value. In this study, the df is obtained which is the same as the number of dependent variables, df = 2. Then the Chi-Square Critical Value: For df = 2 and alpha = 0.01, the Chi-Square critical value ≈ 9.21. Alpha = 0.001, the Chi-Square critical value ≈ 13.82.

Based on the plot of Figure 4, the highest Mahalanobis Distance value is below 5. Since 5 is much smaller than 9.21 (critical value for alpha 0.01) and 13.82 (critical value for alpha 0.001), it can be concluded that there is most likely no multivariate outliers in the data.
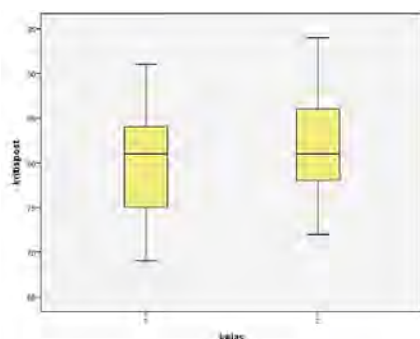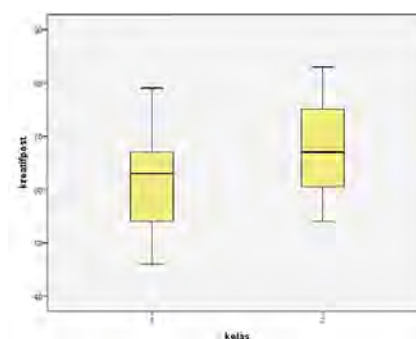
Figure 2. Boxplot of Critical Thinking Skills

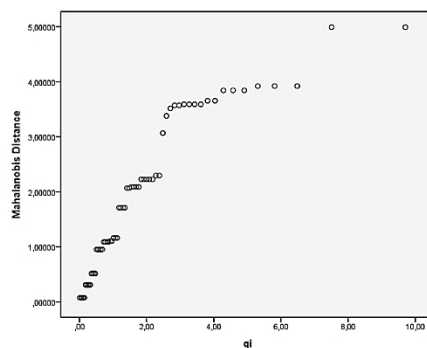

Figure 3. Boxplot of Creative Thinking Skills

Figure 4. Mahalanobis distance versus Chi-square value

Linearity

There is a linear relationship between each pair of dependent variables for each group of independent variables. MANCOVA results often involve understanding how the dependent variables relate to each other in distinguishing groups. If the relationship between variables is not linear, this interpretation becomes difficult and potentially misleading. Linearity is an important assumption in MANCOVA because this method is based on calculating and interpreting linear relationships between variables. Scatterplots are a useful tool for checking this assumption.

Scatterplots are an effective visual way to check for linearity between two variables. If the points on a scatterplot tend to form a straight line (although not a perfect one), this indicates a linear relationship. This means that changes in one variable tend to be followed by proportional changes in the other variable. The straight line can slope upward (a positive relationship: if one variable increases, the other variable also tends to increase) or slope downward (a negative relationship: if one variable increases, the other variable tends to decrease). If the points are randomly scattered without a clear pattern, or form a curved pattern (such as a U-shape or parabola), this indicates that the relationship between the two variables is not linear.
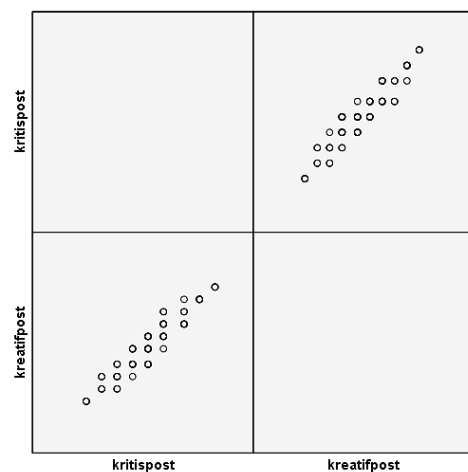

Figure 5. Scatterplot Matrix of Linear Relationships

Scatterplot Figure 5 shows that between the variables of critical thinking skills and creative thinking skills shows a pattern of dots that tend to form a straight line, indicating that the linearity assumption for the pair of variables is met.

Hypothesis Testing

MANCOVA test is used to test the differences between experimental and control groups on the combination of dependent variables, after controlling for the influence of covariates. Multivariate significance is evaluated using several criteria, including Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root.

Table 13. Multivariate Test

		value	F	df1	df2	P
Class	Pillai's Trace	0.804	121.2	2	59	<.001
	Wilks' Lambda	0.1957	121.2	2	59	<.001
	Hotelling's Trace	4.109	121.2	2	59	<.001
	Roy's Largest Root	4.109	121.2	2	59	<.001
Critical pre test	Pillai's Trace	0.971	978.0	2	59	<.001
	Wilks' Lambda	0.0293	978.0	2	59	<.001
	Hotelling's Trace	33.153	978.0	2	59	<.001
	Roy's Largest Root	33.153	978.0	2	59	<.001
Creative pre test	Pillai's Trace	0.271	10.9	2	59	<.001
	Wilks' Lambda	0.7295	10.9	2	59	<.001
	Hotelling's Trace	0.371	10.9	2	59	<.001
	Roy's Largest Root	0.371	10.9	2	59	<.001

Table 13 MANCOVA results show that all four test variables (Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root) have p-values <0.001. There is a highly significant multivariate difference between groups (classes) after controlling for the effects on pre-test critical thinking skills and pre-test creative thinking skills. This means that the intervention or difference between groups has a significant effect on the combination of dependent variables (on post-test critical thinking skills and post-test creative thinking skills).

The next stage, calculation with normalized score gain (n-gain). Calculation with n-gain average critical thinking skills (0.315), is classified as medium. This means that there is a moderate increase in critical thinking skills. This is included in the medium category ($0.3 \le$ n-gain < 0.7). The average n-gain of creative thinking skills (0.178): is classified as low. This means that the increase in creative thinking skills is classified as low. This is included in the low category (n-gain < 0.3). Based on the n-gain analysis, it can be concluded that the intervention given using SIPROMAN digital comic learning media has different impacts on critical and creative thinking skills.

Product Development

In this study, it is known that the material on the Human Reproductive System is often considered complex and quite difficult, supported by the results of the analysis of student needs and interviews with Biology teachers. Both of them highlighted the difficulties in the sub-materials of Anatomy of Reproductive Organs, Menstruation and Understanding the Process of Mechanisms in the Human Reproductive System. The results of the analysis of student needs obtained data that the topics that were difficult for students to understand were 71.7% in the concepts of the Human Reproductive System, namely Sperm Formation (Spermatogenesis), Ovum Formation Process (Oogenesis), Menstruation and 41.5% regarding Anatomical Structure. Interviews with Biology teachers showed that the material on the Human Reproductive System that was less understood was in the sub-materials of Human Anatomy of Reproductive Organs and Puberty, especially Menstruation. This shows that there is cross-validation which strengthens the findings that these two areas are indeed a challenge for students in understanding the material. This is in line with the findings according to Raida, (2018); Tenzer et al., (2022), and Laksmi et al., (2022) stated that many students had difficulties in Puberty, Anatomy, Concepts of the Reproductive System including the concept of Gamete Formation, and Reproductive Health Problems of Organs. Learning about the Human Reproductive System requires comfort and safety, especially when explaining the Anatomy section because students tend to feel embarrassed if they have to ask or search for the vocabulary individually.

The use of learning media in the Human Reproductive System material usually uses PowerPoint, teaching aids, and learning videos. Based on the results of interviews with Biology teachers, learning media is very much needed for visualizing the Human Reproductive System material. Deadara et al.,

(2017) also stated that the Human Reproductive System material does require special understanding because there are several material concepts that cannot be seen directly by the eye so that visual media can be used.

This study presents visual media as SIPROMAN digital comics as an innovation in Biology learning media, especially the Human Reproductive System material. The majority of students (92.5%) agree with the use of digital comics as an innovation in Biology learning media, this shows that most student respondents will receive this idea. Students also have a high interest in learning media innovations when made in the form of digital comics on the Human Reproductive System material as much as 86.8%. Various factors support student interest in digital comic media. The influencing factors are: making it easier for students to learn because it predominantly depicts visuals and is followed by simpler explanations, comics can be connected to contexts and experiences that are relevant to the reader's daily life, digital comics are also in demand because according to students they are more in line with the times and more practical in presentation. Most students are currently familiar with digital technology, especially because of the rapid and more practical development of the technological era (Haka & Suhanda, 2018). The characteristics of these students are also explained by İlhan et al., (2021) that to provide learning materials, examples of students' daily life contexts are needed, using the latest techniques, providing fun learning. In addition, it is known that maintaining students' attention and interest to remain high and for a long time is very difficult, so interesting materials are needed and must be per the learning approach at that time.

Interviews with Biology teachers also support the use of digital comics in schools. This is based on the availability of the internet that supports the use of digital media, including digital comics, making it easier for students to access learning materials inside and outside the classroom. The combination of easy access, interactive features, attractive visuals, and suitability with technological developments make digital comics a popular choice for students (Widyawati & Prodjosantoso, 2015; Şentürk & Şimşek, 2021). This shows that learning and entertainment media continue to adapt to changing times and the preferences of the younger generation (Anggraini & Zulyusri, 2023).

The Design Stage is carried out by designing a clear and detailed product framework containing visual displays, materials, and content that will be developed in the creation of learning media. Based on the main purpose of the design of making this digital comic is so that the message delivery can be more easily understood by the reader. The main topic of the Human Reproductive System material is following the indicators and learning achievements of Biology class XI natural science. The material presented is adapted from relevant Biology textbooks and valid scientific articles. This is important to ensure the accuracy and truth of the information. The language used in the comic is made simpler, easier to understand, and under the level of understanding of students. The material is presented sequentially and logically so that readers can understand the flow of information well.

The development was carried out using a design application, namely Autodesk SketchBook. The development process of the SIPROMAN digital comic produced an initial draft in the form of separate images. The draft was arranged into a series of stories and the panel layout was arranged in the image. The compilation of the SIPROMAN digital comic was made on one long sheet of paper in the Joint Photographic Experts Group (JPEG) format as a requirement for publishing digital comics on the Webtoon platform.

The Webtoon platform was chosen because it can be accessed for free, making it easier for students and teachers (Lestari, 2018). The Webtoon platform can be accessed via the web or applications available on the Play Store and App Store via mobile (Android and iOS) (Lestari & Irwansyah, 2020). The Webtoon platform can be used through several devices such as computers and gadgets as long as they are connected to the internet network. Based on the characteristics of Webtoon according to Jang & Song, (2017), the material in the Webtoon digital comic can be read vertically from top to bottom without interruption (scroll format) so that it can clarify the learning material. There is a comments column below the comic page for discussion between students and teachers. In addition, the Webtoon platform was chosen because of its high number of active users, and more than 6 million Webtoon readers in Indonesia (Apriliani et al., 2022). Indonesia is one of the largest Webtoon markets, so it can be assumed that the contribution of users from Indonesia is very significant (Dewahrani et al., 2023).

Feasibility testing is carried out by several experts such as material experts and media experts. Feasibility testing by experts aims to help reduce the possibility of errors or failures in the use of the product, ensuring that the product functions as it should and meets the established standards.

The SIPROMAN digital comic media feasibility test includes four aspects, namely text (86%), images (84%), stories (84%), and displays (85%). The average media feasibility test was 85%, with a very feasible interpretation that can be used without revision. The text aspect received the highest score, indicating that the text is easy to understand according to the target audience, informative, and grammatically correct. This is very important because good text will support the effectiveness of comics as a learning medium and ensure that the message to be conveyed can be well received by the reader. The image, story, and display aspects were also considered very good. This aspect shows the quality of the visual display, an effective and motivating storyline, and good ease of navigation.

The feasibility test of SIPROMAN digital comic materials includes two aspects: materials (86%) and learning (88%). The average feasibility test of materials is 87%, indicating that the comics are very suitable for use without revision. The material aspect assesses the content, including suitability with learning indicators, reliable sources, depth of material, and interrelationships between concepts. The learning aspect assesses the presentation of materials and their impact on the learning process, including systematic (logical and structured sequence), effectiveness (achieving learning objectives), and efficiency (brief and concise presentation). This presentation aspect gets the highest score. The logical presentation structure and breaking down information into small parts make it easier for students to understand the material (Brunken et al., 2003; de Jong, 2010). This helps reduce cognitive overload and allows students to process information gradually so that understanding is more optimal (Koć-Januchta et al., 2022).

After the feasibility test is completed by experts, implementation will be carried out. The implementation of the product was carried out on Biology teachers of class XI natural science Muhammadiyah 4 Senior High School Jakarta and groups of class XI natural science students referred to as small or large group tests. Group testing is carried out to obtain feedback from users who represent actual users.

Teachers' responses to the SIPROMAN digital comic were assessed based on four aspects: material (88%), presentation (86%), language (94%), and benefits (79%). Overall, the trial score by teachers was 87%, with a very decent interpretation and can be used without revision. The material and presentation aspects were assessed as very good, indicating that the material was relevant, accurate, and informative, and the presentation was effective and easy to understand. The language aspect received a very high score, indicating that the language used was clear, easy to understand, and appropriate for students. This high score indicates that the SIPROMAN comic was successful in terms of verbal communication, ensuring that messages and information were conveyed clearly and effectively to readers. The benefits aspect received the lowest score, although it was considered useful, teachers provided input for further development, for example, emphasizing the improvement of critical thinking skills, creative thinking skills, and student motivation.

Kaufman & Wandberg, (2010) stated that group testing aims to identify the advantages and disadvantages of product design before evaluation. The group trial instrument consists of four aspects: material, presentation, language, and benefits. In the small group test, the average score was 94% (material 95%, presentation 94%, language 93%, benefits 93%), and in the large group test, the average score was 92% (material 92%, presentation 92%, language 92%, benefits 91%). The difference in scores between the two groups was relatively small (2%), indicating the consistency of positive learning experiences. The combination of expert assessments, Biology teachers, and students (group test) provided a strong positive assessment that the SIPROMAN digital comic was interesting, effective, and useful. Thus, the development of the SIPROMAN digital comic was considered successful and ready to be used in learning.

Effectiveness of Critical Thinking Skills and Creative Thinking Skills

Evaluation of the effectiveness and efficiency of the product is carried out by assessing the critical thinking skills and creative thinking skills of students. Effectiveness testing is important to measure the effectiveness of learning media (Ichsan, 2017). MANOCVA test analysis shows significant differences between groups (p <0.001). Learning the Human Reproductive System with SIPROMAN digital comics is effective because of its innovative and easy-to-understand visual and narrative approach. Structured visualization and concise narratives in comics help translate information step by step (Azka et al., 2016). Breaking down complex material into small parts and gradual presentation, supported by clear visualization, is in line with the principles of constructivism. The use of constructivism principles can facilitate the construction of meaningful knowledge, reduce cognitive load, increase engagement, and provide relevant context (Vogel-Walcutt et al., 2011). Therefore, digital comics with this approach produce more effective and efficient learning. On the other hand, poor presentation of material, unstructured, and excessive information increase the burden of loading information (Arnold et al., 2023). Based on the n-gain analysis, the use of SIPROMAN digital comic learning media has different impacts on critical and creative thinking skills. Critical thinking skills showed a moderate increase with an average n-gain of 0.315 (Hake, 1998), while creative thinking skills only experienced a low increase with an average n-gain of 0.178 (Hake, 1998).

This may be due to factors such as too short or lack of frequency in studying the Human Reproductive System material with the help of SIPROMAN digital comics. Significant changes in improving critical thinking skills and creative thinking skills will occur if given enough time and practice. If students are only given digital comics in a few short sessions, the impact may not be optimal. This is in line with the dual coding theory put forward by Paivio, (2010) explaining that information is processed and stored in memory into two forms: verbal (language) and non-verbal (visual). When information is presented in both formats, understanding and retention increase. In the context of SIPROMAN digital comics, the combination of text and images supports dual coding and facilitates learning. However, to develop critical thinking skills and creative thinking skills, students need more than just understanding information, they

need to process it deeply and apply it in different contexts. This process takes a long time and practice. In addition to the duration of use, differences in motivation and interest between students in the experimental and control classes may also affect these results. If students in the experimental class are more motivated or more interested in the Human Reproductive System material, they may be more actively involved in learning and show greater improvement. They are also more likely to persist in the face of learning difficulties in the Human Reproductive System material, rather than giving up easily.

The cognitive characteristics of students, such as initial critical thinking skills and creative thinking skills, as well as learning styles also play a role. If students in the experimental class have higher initial skills or learning styles that are more suited to the learning method, they may show more significant improvements and vice versa with the control class.

Finally, the evaluation method used also needs to be considered. A more comprehensive evaluation, not only focusing on pre-test and post-test scores, but also the learning process, student interaction using digital comics, classroom observations, interviews, and analysis of student work results, can provide more in-depth information. This more in-depth assessment can include student activeness in discussing, asking questions, and providing comments during the use of SIPROMAN digital comics.

Conclusion

SIPROMAN digital comic learning media on the human reproductive system material has been developed and received an assessment with the interpretation that it is very suitable for use as a learning medium and has been proven effective in improving critical thinking skills and creative thinking skills.

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author Contributions

S. P. Apriani: methodology, analysis, writing original draft preparation, review and editing; **S. Supriyatin:** review and editing and **R. Rusdi:** review and editing.

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