ISSN: 0215-9643 e-ISSN: 2442-8655

The Effectiveness of Android-Based E-Comics in Improving Students' Understanding of Mixture Separation Concepts in Grade X Vocational High Schools

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ARTICLE INFO

Article history
Received March 18, 2025
Revised June 09, 2025
Accepted June 30, 2025

Keywords
E-comic
Android
Material separation
Plomp model
Aiken's formula

ABSTRACT

This research aims to explore the influence of Android-based electronic comics on tenth-grade vocational students' understanding of the concept of mixture separation. A quantitative approach within a quasi-experimental design is utilized to conduct the study., involving two groups: an experimental class using e-comics and a control class using conventional learning media. The research subjects were 10th grade students at SMKN 7 Kota Batam, while the object of research was students' conceptual understanding of mixture separation material. Data were collected using a conceptual understanding test administered before (pretest) and after (posttest) the treatment. The analysis of the data included normality and homogeneity tests, along with an independent samples t-test to evaluate differences in posttest outcomes between the experimental and control groups. Findings revealed that students in the experimental group achieved notably higher posttest scores than those in the control group. The t-test result was t (78) = 9.042 with a p-value of 0.000, which is below the 0.05 sig level, and the mean score difference was 14.800. These results confirm that the integration of Android-based e-comics sig enhanced students' understanding of the concept.

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I. Introduction

Education is the cornerstone in preparing the younger generation to face future challenges. In the context of vocational education, for example, SMK, the relevance between learning materials and real-world applications becomes crucial (Khairiyah et al., 2024; Riyanto et al., 2025; Rohaeni et al., 2021). Chemistry, as one of the core subjects, plays a vital role in various vocational fields (Dyachenko et al., 2024; Qi et al., 2024; Shwartz et al., 2021). Chemistry is a subject rich in concepts; therefore, a proper understanding of the fundamental concepts that underpin these chemical concepts is essential (Blackie, 2022; Carle & Flynn, 2020; Taber, 2020). Suppose students do not develop a solid understanding of these fundamental concepts. In that case, they are likely to face significant difficulties when attempting to grasp more advanced materials that require higher-order thinking and practical application, both in everyday situations and within professional environments. (Chen, 2024; Tian, 2024).

One of the significant challenges faced by general subject teachers at vocational schools, particularly chemistry teachers, is the low motivation of students to learn subjects that are not directly related to the skills or majors they are studying (Ardhaoui et al., 2021; Musengimana et al., 2021; Salta & Koulougliotis, 2020). Most vocational school students have a learning orientation that is more focused on material that supports their vocational skills, so subjects such as chemistry are often considered irrelevant and of little benefit to their future careers (Kovalchuk et al., 2022; Sangsawang, 2020; Skarpaas & Hellekjær, 2021). Consequently, students tend to exhibit limited enthusiasm for learning and engage only minimally during instructional activities. This situation presents a distinct challenge for educators, who must seek out effective teaching strategies and instructional media capable of bridging the gap between chemistry content and students' everyday lives. By doing so, teachers can help rekindle students' interest and encourage more active involvement in the learning experience. (Ramadhani et al., 2023; Xayrullo o'g & Rajabboyovna, 2024; Yao, 2023).

Observations conducted in the field reveal that vocational high school students generally demonstrate low motivation when it comes to learning chemistry, especially regarding the topic of mixture separation. Insights gathered from teacher interviews and classroom

http://dx.doi.org/10.17977/um048v31i1p148-157

observations suggest that a significant number of students view chemistry as a challenging subject with little relevance to their vocational interests or career paths. As reflected in their daily grades, most of which have not yet achieved proficiency. This situation suggests that most students have not fully grasped the material, particularly the fundamental concepts of chemistry. This low level of understanding is thought to be caused by a lack of initial preparation, low science literacy, and underdeveloped logical thinking skills, making it difficult for them to understand scientific processes such as filtration, distillation, and chromatography. Additionally, the material on mixture separation is complex and challenging for 10th-grade vocational high school students.

According to Muhammad et al. (2025), over 60% of students struggle to grasp the fundamental principles of separation methods, including filtration, distillation, chromatography, and decantation, primarily due to the scarcity of contextual and visual learning materials, which in turn affects their conceptual understanding and overall learning outcomes. The characteristics of vocational high school students, who tend to prefer visual and practical learning, make them less interested in presentations that are purely textual and theoretical (Buckley & Nerantzi, 2020; Palioura & Dimoulas, 2022). This mismatch reduces students' interest, motivation, and understanding. Although vocational high school students are generally familiar with digital devices such as smartphones and tablets, these have not been optimally utilized in learning (Lang & Šorgo, 2023; Malik et al., 2024; Purmadi et al., 2022). Therefore, it is necessary to develop interactive, visual, and contextual learning media, such as Android-based e-comics that present separation of mixed materials in an interesting, easy-to-understand, and student-centered manner.

E-comics offer a lot of potential to boost students' motivation and interest in learning, and understanding of concepts, especially in chemistry learning (Damayanti et al., 2024; Pradnyasari et al., 2024; Rafidah et al., 2022). Wicaksono et al. (2020) stated that Electronic comics have the potential to stimulate greater student engagement by fostering a more interactive and participatory learning environment, while Sinta et al. (2021) emphasized that e-comics have a positive effect on the understanding of chemistry concepts. This aligns with the views of Putra and Milenia (2021), who state that e-comics are designed with entertaining and engaging illustrations, thereby sparking students' curiosity. E-comics combine narrative text with visual illustrations in the form of stories, making it easier to convey scientific concepts in an engaging and easily understandable manner. Based on Clark and Mayer's (2021) multimedia learning theory, the combination of text and images can enhance understanding by activating two information processing channels: verbal and visual.

Additionally, Android-based e-comics offer flexibility in terms of time and place for learning, supporting 21st-century learning principles and the concept of self-directed learning. Research by Han et al. (2020) also indicates that digital comic media is effective in enhancing students' motivation and learning outcomes in science subjects.

However, based on these studies, there has been no research testing the effectiveness of e-comics on mixture separation material at the elementary level in improving students' conceptual understanding, making this research important. Accordingly, the objective of this research is to evaluate how effective the use of e-comics is in enhancing the conceptual understanding of tenth-grade vocational high school students on the topic of mixture separation.

II. Method

A. *Type of Research*

This study uses a quantitative approach to objectively test the effectiveness of Android-based e-comics in improving students' understanding of the concept of mixture separation. This approach involves collecting numerical data in the form of pretest and posttest scores, as well as inferential statistical analysis to test the proposed hypothesis. The quantitative method was chosen because it allows for systematic measurement of the effect of the treatment (use of e-comics) on student learning outcomes, as well as supporting the generalization of findings based on statistically measurable data.

B. *Research Subjects*

The research subjects consisted of 80 tenth-grade students at SMK Negeri 7 Batam in the even semester of the 2024/2025 academic year, divided into two groups: an experimental class and a control class, each consisting of 40 students. The experimental class received instruction using Android-based e-comic media, while the control class underwent conventional instruction without the use of such media. The selection of subjects in equal numbers aims to ensure a fair comparison between the two groups in testing the effectiveness of e-comic media on improving students' conceptual understanding.

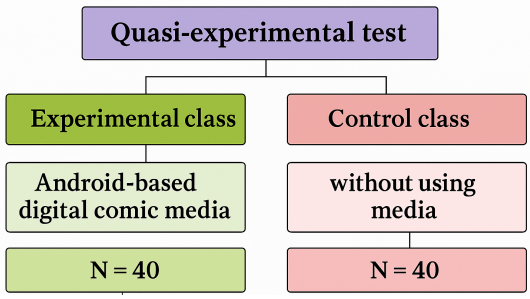


Fig. 1. Quasi-experimental test design

C. *Data Collection Instruments*

To gather data in this study, researchers utilized tests designed to assess students' understanding of the concepts,

which were conducted both before the instructional intervention (pretest) and following its completion (posttest). These tests were designed to measure students' mastery of the material on mixture separation. Furthermore, questionnaires were employed to collect information regarding students' perceptions and reactions toward the implementation of e-comic media during the learning activities. The use of these two types of instruments allows researchers to evaluate the effectiveness of the media not only from a cognitive perspective (learning outcomes) but also from an affective perspective, such as motivation and interest in the material.

D. Data Analysis Techniques

Data analysis was performed quantitatively using SPSS 21 software, with stages including normality testing, homogeneity testing, and t-testing (independent sample t-test). Normality testing aims to determine whether the data is normally distributed, with a significance criterion of > 0.05 indicating normal data. If the data meet the assumptions of normality and homogeneity of variance (also with a significance level > 0.05), then the t-test is conducted to test the hypothesis. The study's analysis reveals a statistically significant disparity in posttest scores between the experimental and control groups, as evidenced by a p-value below the 0.05 threshold. The class using Android-based e-comic media demonstrated higher conceptual understanding compared to the control group that did not use the media, proving the effectiveness of e-comic use in chemistry learning.

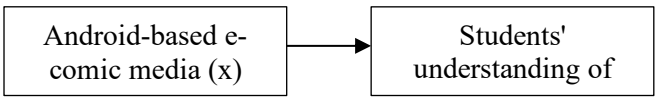


Fig. 2. Research framework

Description:

H0: There is no effect of using Android-based e-comic media on the conceptual understanding of tenth-grade students in the subject of Mixture Separation.

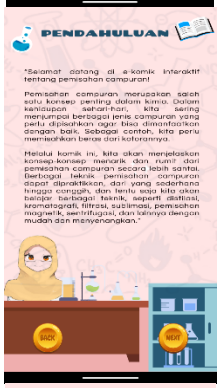
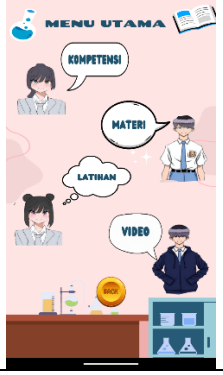
Ha: There is an effect of using Android-based e-comic media on the conceptual understanding of tenth-grade students in the subject of Mixture Separation.

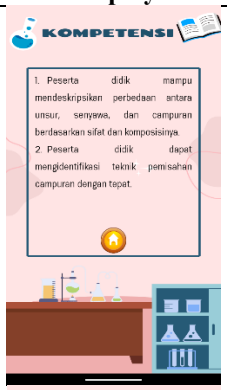
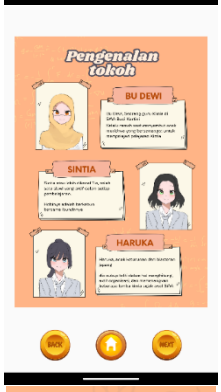
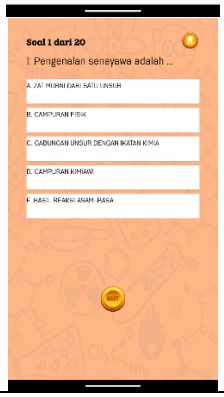
III. Results and Discussion

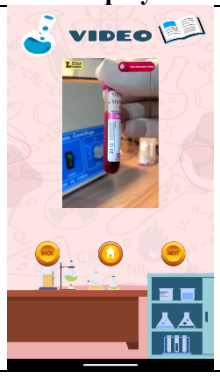
A. Description of E-Comic Media

The media used in this study is an Android-based e-comic about mixture separation to improve the conceptual understanding of 10th-grade vocational high school students. This e-comic is designed to support active, contextual, and meaningful learning processes. The following is a brief explanation of the e-comic media that will be used in the experimental class.

Table 1. e-comic Media display

No	Display	Description
1.		The first page that will appear is the cover of the e-comic.
2.		Introduction
3.		Instructions for use
4.		main menu

No	Display	Description
5.		Competence
6.		Materials
7.		Sub-subject
8.		Practice

No	Display	Description
9.		Video

This media has undergone a validation and practicality assessment process conducted by lecturers, teachers, and students. Experts carried out the assessment stage through a validation process of the created e-comic. This validation involved five validators who assessed the material and media of the created e-comic. The analysis of the validation results was conducted using Aiken's V method, which aims to measure the validity level of each statement assessed by the validators. The results of the material validation analysis are presented in Appendix 8, while the Findings of the media validation analysis are presented in Appendix 10. These validation results serve as the basis for researchers to enhance the quality of the product before further implementation in field trials.

Table 2 displays the findings of the data analysis of the generated e-comic's material validation assessment.

Table 2. Material Validity Test Data

No.	Aspects assessed	Value
1.	Content Aspects	0,95
2.	Presentation Aspects	0,95
3.	Language Aspects	0,93
4.	Contextual Aspects	0,93
Average		0,94

Table 2 shows that the evaluation of the four factors considered in the creation of the e-comic has a valid classification with an average value of 0.94 from the material validator's validation test. Table 3 displays the findings of the examination of the media validation test evaluation of the created e-comic.

Table 3. Media Validity Test Data

No.	Aspects assessed	Value
1.	Display Aspects	0,94
2.	Programming Aspects	0,94
3.	Utilization Aspects	0,94
Average		0,94

According to the data presented in Table 3, the assessment of the three aspects evaluated in the developed e-comic obtained an average score of 0.94 from the media validator's validation test, which is categorized as valid.

Table 4 displays the overall findings of the validation test analysis of the created Android-based e-comic.

Table 4. Overall Validation Test Data

No.	Aspects assessed	Assesment	Category
1.	Material Validation Test	0,94	Valid
2.	Media Validation Test	0,94	Valid
Average		0,94	Valid

According to the data presented in Table 4, the validation test results for the e-comic developed are categorized as valid with an average value of 0.94.

Based on the outcomes of a few field tests, practicality testing was done to ascertain the usability and practicality of the generated e-comic. This practicality assessment provides an overview of the degree to which educators may employ e-comics in the teaching and learning process. Table 5 provides comprehensive information on the outcomes of teachers' practicality tests.

Table 5. Teacher Practicality Test Data

No.	Aspects assessed	Assesment
1.	Useful aspects	100
2.	Easy-to-use aspects	100
3.	Attractive aspects	95
4.	Clarity aspects	100
5.	Efficiency aspects	96
Average		98

According to the data presented in Table 5, the assessment of the five evaluated aspects achieved an average of 98%, with a very practical category.

In addition, a one-to-one practicality test was conducted on three students representing high, medium, and low ability categories. The purpose of this test was to determine the extent to which the developed e-comic could be used effectively and easily understood by students with different academic backgrounds. This practicality sheet instrument consists of four components. The analysis of the one-to-one practicality test can be seen in Table 5.

Table 6. Results of the One-to-One Practicality Test

No.	Aspects assessed	Assesment
1.	Convenience	97
2.	Appeal	83
3.	Efficiency	93
4.	Benefits	93
Average		92

From the four items assessed, an average of 92% was obtained, indicating that the developed e-comic achieved the category of very practical across all four assessment components. The small group practicality test was also conducted on nine students with varying abilities: high, moderate, and low. The analysis of the small group practicality test can be seen in Table 7.

Table 7. Small Group Practicality Test Results

No.	Aspects assessed	Assesment
1.	Convenience	98
2.	Appeal	92
3.	Efficiency	100
4.	Benefits	97
Average		97

From the four items evaluated, an average of 97% was obtained, meaning that the built e-comic received the "efficient" category for all four evaluation components. The practicality results for one-to-one and small group students can be seen in Table 8.

Table 8. Overall Results of the Practicality Test for Students

No.	Aspects assessed	Assesment
1	One to one	92
2	Small group	97
Average		95

Based on Table 8, both practicality test methods (one-to-one and small group) showed consistent results with an average score of 95%. This score meets the overall practicality criteria. The practicality results for teachers and students can be seen in Table 9.

Table 9. Overall Results of the Practicality Test

Class	Kolmogorov-Smirnov Statistic	df	Sig.	Shapiro-Wilk Statistic	df	Sig.
Pretest Control Class	0.102	40	0.200*	0.973	40	0.458
Posttest Control Class	0.120	40	0.149	0.948	40	0.067
Pretest Experimental Class	0.148	40	0.028	0.949	40	0.069
Posttest Experimental Class	0.106	40	0.200*	0.945	40	0.053

Based on Table 8, the practicality test results show high consistency between teacher evaluations (98%) and student evaluations (95%). The average achievement of 97% indicates that the built e-comic meets the criteria for being highly practical.

B. Preliminary Test Results

Prerequisite tests are a series of statistical tests conducted before the main analysis to ensure that the data used meets the basic assumptions of the analysis technique to be used, especially in parametric statistical analysis. The most common prerequisite tests are normality tests and

homogeneity tests. Shapiro-Wilk was employed in this study's normality test with SPSS 21.

Table 10 displays the data analysis's findings.

Table 10. Results of Normality Test

Results	Kolmogorov-Smirnov			Shapiro-Wilk		
Class	*Statistic*	*df*	*Sig.*	*Statistic*	*df*	*Sig.*
Pretest Control Class	0.102	40	0.200*	0.973	40	0.458
Posttest Control Class	0.120	40	0.149	0.948	40	0.067
Pretest Experimental Class	0.148	40	0.028	0.949	40	0.069
Posttest Experimental Class	0.106	40	0.200*	0.945	40	0.053

For both the control and experimental classes, the normality test findings yielded a posttest significance value of > 0.05 using the Shapiro-Wilk method. This suggests that the values of both groups follow a normal distribution. The second test conducted was the homogeneity test, which was performed on the control and experimental classes. The conclusions can be seen in Table 11.

As can be shown from the preceding table, the significance value is > 0.05. In light of this, the data values acquired are uniform.

C. *Analysis of the Effect of E-Comic Media Use on Students' Conceptual Understanding*

A t-test was performed to assess whether the use of the developed e-comic had a measurable effect on students' academic performance. To determine this, post-test scores from both the experimental and control groups were analyzed. The conclusions of the hypothesis test are presented in Table 12.

Table 11. Homogeneity Test Results

Result	Levene Statistic	df1	df2	Sig.
Based on Mean	1.145	1	78	0.288
Based on Median	1.052	1	78	0.308
Based on Median and with adjusted df	1.052	1	77.012	0.308
Based on Trimmed Mean	1.191	1	78	0.278

Table 12. Hypothesis Test Results

Levene's Test for Equality of Variances				t-test for Equality of Means		
F	*Sig.*	*t*	*df*	*Sig. (2-tailed)*	*Mean Difference*	*Std. error defiance*
Equal variances assumed	1.145	0.288	9.042	78	0.000	14.800
Equal variances not assumed			9.042	75.654	0.000	14.800

A t-test was performed to assess whether the use of the developed e-comic had a measurable effect on students' academic performance. To determine this, post-test scores from both the experimental and control groups were analyzed. The results of the hypothesis test are presented in the table below. The average learning outcomes of students who used the developed e-comics were higher than those of students who did not use them.

As illustrated in Figure 3, the average pre-test score was 44.3 for the control group and 45.8 for the experimental group, indicating that both groups had relatively equal levels of initial understanding. After the implementation of the learning media, there was a significant increase in post-test scores, with the control class achieving an average of 73.6 (an increase of 68.37%). In comparison, the experimental class achieved 88.4 (an increase of 92.83%). The higher growth in the experimental class indicates that the use of Android-based e-comics contributes positively and more effectively to improving students' conceptual understanding compared to conventional learning methods without such media.

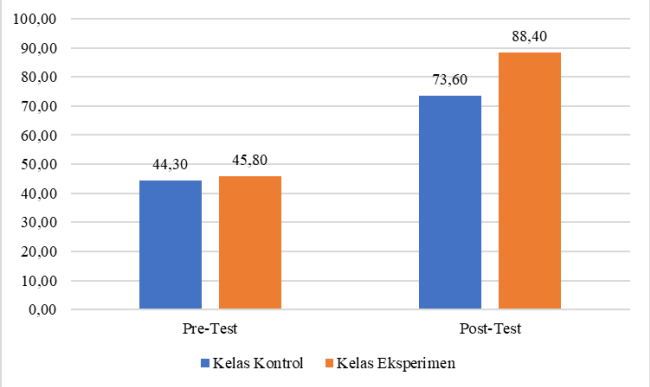


Fig. 3. Pre-test and post-test results for the experimental and control classes.

Table 13. Student Learning Outcomes Post-Test in Experimental Classes

No	Student	Control	Experiment	No
1	A	68	92	1
2	B	60	96	2
3	C	68	92	3
4	D	72	96	4

No	Student	Control	Experiment	No
5	E	84	100	5
6	F	68	88	6
7	G	76	88	7
8	H	64	76	8
9	I	72	76	9
10	J	68	92	10
11	K	76	88	11
12	L	76	92	12
13	M	76	80	13
14	N	72	88	14
15	O	76	96	15
16	P	80	92	16
17	Q	80	88	17
18	R	72	88	18
19	S	84	92	19
20	T	68	80	20
21	U	76	92	21
22	V	76	84	22
23	W	76	92	23
24	X	68	84	24
25	Y	84	84	25
26	Z	64	96	26
27	AA	60	88	27
28	AB	72	96	28
29	AC	80	84	29
30	AD	80	76	30
31	AE	72	84	31
32	AF	84	80	32
33	AG	68	100	33
34	AH	64	88	34
35	AI	72	80	35
36	AJ	72	84	36
37	AK	80	76	37
38	AL	80	100	38
39	AM	72	100	39
40	AN	84	100	40

Referring to the post-test results presented in Table 13, it is evident that students in the experimental group consistently outperformed those in the control group. The average score in the experimental class demonstrated a notable improvement, with most students earning scores above 84, and several attaining the maximum score of 100. Meanwhile, the scores of students in the control class tend to be lower, ranging from 60 to 84. This comparison highlights the positive impact of utilizing Android-based e-comic learning media in enhancing students' academic performance, especially in their comprehension of the topic related to mixture separation. Therefore, it can be concluded that learning using e-comics is more effective than conventional learning.

The study's findings suggest that e-comic media can help grade X vocational high school students better grasp the idea of mixture separation. This is supported by the t-test results, which revealed a statistically sig difference in post-test scores between the experimental and control groups. The analysis produced a t-value of 7.058 with 78 degrees of freedom and a two-tailed significance level of 0.000 ($p < 0.05$).

The pretest results show that the experimental class had a score range of 28–60, while the control class had a range of 24–68. This indicates that the initial knowledge of both classes was relatively equivalent, and no significant learning intervention had yet been implemented. This initial knowledge was also influenced by whether students completed reading assignments before the lesson, which served as an external variable affecting the pretest scores.

Following the implementation of e-comics in the experimental class, a notable improvement in post-test scores was observed. Students in the experimental group achieved scores ranging from 72 to 100, whereas the control group, which did not utilize e-comics, showed a more modest increase with scores ranging from 60 to 96. The difference in the score range shows a higher increase in the class that used e-comics, not only in terms of the average score but also in terms of the consistency of the minimum score increase. This fact shows that e-comic media not only helps high-achieving students but also improves the understanding of students with lower abilities, who were previously lagging behind in the pretest.

The developed e-comic media successfully overcame the main obstacle in chemistry learning at vocational high schools, namely the low interest of students in general subjects that do not align with their majors. Visualization in the form of comics, combined with light yet informative narratives, enhances students' absorption of complex scientific concepts (Matuk et al., 2021; Reyes & Villanueva, 2024; Wang et al., 2021). E-comics also facilitate independent learning as they can be accessed anytime via Android devices, making them an adaptive learning tool suited to the learning habits of students in the digital age (Jannah & Putra, 2024; Khairunnisak et al., 2024; Suri et al., 2021).

In addition to cognitive benefits, the use of e-comics also stimulates learning motivation. Students reported that this medium is engaging, enjoyable, and motivates them to explore the material more deeply (Fitriani & Leton, 2024; Prinandari & Sahrina, 2024; Rasmet et al., 2025). This is key to fostering learning initiative, especially among vocational high school students who tend to disregard exact sciences if they are not directly linked to their vocational competencies (Abrassart & Wolter, 2020; Lent & Brown, 2020; Young & Hordern, 2022).

In terms of cognitive achievement and learning interest, it can be inferred from the pre and post test results as well as student reactions that Android-based e-comics are successful in enhancing students' comprehension of the idea of mixture separation. These findings are consistent with previous research emphasizing the role of interactive visual media in bridging the gap between students' understanding and abstract theoretical concepts.

IV. Conclusion

According to the study's findings, grade X vocational high school students' comprehension of the concept of mixture separation can be enhanced using Android-based e-comics. The effectiveness is demonstrated by a statistically sig t-test result ($t = 7.058$; $p < 0.05$), along with the experimental group's higher and more consistent post-test scores compared to those of the control group. E-comics can increase students' desire and interest in chemistry. This subject has historically been viewed as dull, while also bridging the knowledge gap between students with high and low beginning ability. The light visualization, communicative narrative, and accessibility via Android devices make this medium highly suitable for the characteristics and learning habits of vocational high school students in the digital age. Nevertheless, there are several limitations in this study that future researchers should take into consideration. One limitation is the presence of external variables that are difficult to control, such as students' habits of reading materials before class begins, which can influence pre-test results. In addition, the content covered in this study was confined solely to the topic of mixture separation so the effectiveness of the e-comic for other chemistry topics cannot be conclusively determined. Therefore, future researchers are advised to develop more interactive and innovative e-comics and expand their application to other chemistry materials to test the consistency of their effectiveness in various learning contexts.

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