



Original Research

Exploring the Influence of Gamified Digital Learning on Student Engagement and Learning: A Case Study on Using Interactive Comics to Study Pancasila

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Abstract: This study investigates the engagement of students studying Pancasila (i.e., Indonesian philosophy) through interactive comics, with consideration of their backgrounds and reading habits. The data were collected through a survey delivered via Google Forms. The subjects were first-year students at Petra Christian University (PCU) studying Pancasila through interactive comics. The data were explored using descriptive statistics, hypothesis testing, and machine learning. We found that 72.55 percent of the respondents understood the material delivered through the interactive comics in detail. In addition, they described the method as fun. The hypothesis testing showed that the students were able to study Pancasila through interactive comics successfully regardless of their background (e.g., gender, GPA, living situation, major), reading preferences, and average reading duration. However, students' majors influenced the opinion that interactive comics led to a more interesting, up-to-date, and fun learning experience. Students who generally like e-books preferred learning Pancasila through interactive comics over conventional methods, and students who like reading novels concluded that learning Pancasila through interactive comics helped them study. Ultimately, 62.75 percent of the participants recommended exploring Pancasila through interactive comics. Based on the data, we can recommend using this approach.

Keywords: *Digital Immersion, Pancasila, Reading Habits, Machine Learning*

Introduction

The COVID-19 pandemic, which began spreading around the world in early 2020, significantly impacted all aspects of life, including education. Teaching that was originally carried out in the classroom was moved online. When viewed positively, this brought about the "Metaverse era" in education. In the Metaverse, students can build skills, explore, and share in a virtual space without barriers (Pimentel et al. 2022). During the pandemic, classrooms became borderless; students were able to learn wherever they were. However, online learning also has downsides. One of the negative aspects is that it is less able to address the needs of the digital native generation. These individuals tend to be digitally literate, always connected, multitasking, and experimental; they prefer to work in teams and learn in visual or kinesthetic ways (Vitvitskaya et al. 2022).

To address students' lack of interest and motivation for learning, recent studies in education have used gamification and various activities (Oliveira et al. 2022). Metwally et al. (2021) have shown that gamification can increase student concentration, interest, and performance. It can also reduce frustration and demotivation. Recent reviews of gamification in education have been produced by Oliveira et al. (2023) and Zeybek and Saygi (2023).

Responding to this challenge, Petra Christian University (PCU) launched Petraverse. Petraverse is a gamification-based Learning Management System (LMS) with immersive digital learning modules. There are four types of learning modules integrated with the LMS: visual novels, comics, role-play games (RPG), and virtual reality (VR; see Figure 1). Petraverse provides a skill card feature to measure the development of soft skills, factions for interaction and collaboration spaces, and rewards as part of the assessment process. If implemented appropriately, Petraverse enables students to keep pace with offline learning and make the experience fun and engaging.

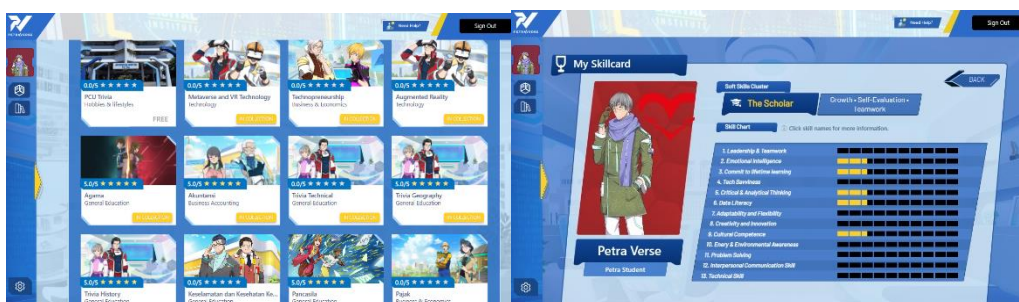


Figure 1: Module and Skill in Petraverse¹

Pancasila is the foundational ideology of Indonesia, comprising five principles: belief in one God, just and civilized humanity, the unity of Indonesia, democracy guided by consensus, and social justice. It shapes the nation's values, governance, and social harmony. From kindergarten to college, all Indonesian students must study Pancasila because it plays a crucial role in nurturing a sense of national identity, fostering unity, and promoting democratic and ethical values. Traditionally, students learn about Pancasila from classroom lectures. This paper, however, focuses on a Pancasila learning module (Bustan and Latif 2023) delivered through interactive comics via Petraverse. It has a time-travel storyline, animation, voice dubbing, and interactive quizzes.

This study explores the influence of gamified digital learning on student engagement and education based on their reading habits. We hypothesize that students with strong reading habits, particularly those who read comics, will engage with learning Pancasila through interactive comics more fully. Additionally, this study aims to determine the qualities that prompt students to suggest interactive comics to their friends. The research also

¹ Please note that the images in this article were copied directly from the original source.

aims to find out the perceived shortcomings of this medium to address students' needs and make Pancasila courses more engaging (Figure 2).

The structure of this paper is as follows: Section 2 reviews the previous literature on gamification and learning engagement. Section 3 conveys the proposed methodology. Section 4 displays the results of the analysis in accordance with the collected data. Finally, Section 5 concludes the study.



Figure 2: Module Pancasila as an Interactive Comic in Petaverse

Literature Review

Even though schools are as active as before, innovations in digital learning should be promoted, as they allow students to learn whenever and wherever they want. There has been a significant amount of research on the use of games in education, including one study explaining the innovative and creative use of videos and games in the learning process (Cheung and Ng 2021). There have also been many reviews on gamification in education (Dichev and Dicheva 2017; Koutníková 2017; Krath, Schürmann, and von Korfflesch 2021; Mee Mee et al. 2020). A study on applying visual novels to learn Pancasila has also been carried out in Indonesia (Andrew et al. 2019). Kartika Sari et al. (2022) developed digital comics for thematic learning for grade 5 elementary school students.

Digital learning has been evaluated extensively, including a quasi-experimental study involving a Google sites-based project that examined students' critical reflection, learning motivation, and performance in the foreign language classroom (Nguyen 2022). Another study evaluated the use of online comics at the Indonesia Open University (Radeswandri, Vebrianto, and Thahir 2021). Da Silva et al. (2017) identified strategies for using comics to teach students in management programs.

Gamification

Gamification is the process of incorporating game elements into non-gaming activities, such as education or business. Gamification increases user interest and motivation (Nah et al. 2014). It involves using game mechanics, such as points, badges, leaderboards, challenges, and prizes, as incentives for participants to participate and perform desired actions (Dichev and Dicheva 2017).

The aims of gamification are to make given tasks more fun and interesting, encourage participants to learn and develop new skills, and motivate them to achieve the goals set at the beginning of the learning process. Other benefits of gamification are increasing understanding and retention of learning materials, encouraging cooperation and healthy competition among students, providing timely and continuous feedback, and helping students develop social and emotional skills such as teamwork and self-control (Ryan 2022).

The Negative Side of Gamification

Although gamification can be effective in particular learning contexts, it is only a solution to some problems and is not necessarily suitable for use in other situations. In addition, there are ethical issues related to maintaining participant privacy and fairness when designing gamification systems. For example, problems of dishonesty can arise, and participants sometimes lack understanding of the material presented (Almeida et al. 2023; Diefenbach and Müssig 2019)

Another negative side of using gamification in education is that students may become dependent on the prizes given, reducing the quality of learning. It can also trigger negative competitive behavior among students, and there is the possibility that they may engage in manipulation to obtain prizes. These negative effects require special attention from educators if they are to be minimized.

Comics as a New Learning Medium

Comics have a long history: they began with works of pictorial art found in ancient Egypt and China. However, the comic book itself began in the nineteenth century when an artist named Rodolphe Topffer created illustrated narrative books for children, which became very well-known in Europe. In the twentieth century, various comic works were increasingly recognized in America and Japan. More recently, digital comics have become mainstream (Booker 2014).

Comics have been recognized as a learning medium with various benefits in the 21st century. These benefits include increasing students' motivation, understanding of the material, visual literacy skills, creativity, and imagination (Pange 2023). They are more widely accepted as a learning medium at the elementary and middle school levels. However, it is likely that the same benefits will also be found at the undergraduate level. Material that is usually learned by rote can be presented as an exciting story to help students understand (Neo and Mitchell 2019).

Engagement

Engagement in a digital learning module refers to the level of active and meaningful involvement that learners exhibit while interacting with its content, activities, and features. It indicates how interested, attentive, and motivated learners are to participate and learn. An engaged learner not only completes required tasks but also invests genuine effort in comprehending and absorbing the information, resulting in a richer understanding of the subject matter. Engagement is crucial

as it leads to a favorable and motivating learning environment, ultimately contributing to a more productive educational experience for all students.

Measuring engagement is crucial to assess the effectiveness of a digital learning module and improve it. In this study, we measure learners' perceptions, including the ease of understanding the materials, to determine if they understand faster when studying Pancasila with interactive comics. We also ask how likely they are to recommend the module to others (Rajabalee and Santally 2021; Appleton and Silberglitt 2019).

Methods

This section presents the proposed methodology in this study in four stages. First, it discusses the data collection process, which was done through a survey. Second, the data description and hypothesis testing processes are described. Third, it identifies the predictions about students' willingness to recommend learning Pancasila through interactive comics to their peers. The classification was conducted through a single classifier, ensemble, and artificial neural network approaches. Last, it considers the performance metrics and feature importance.

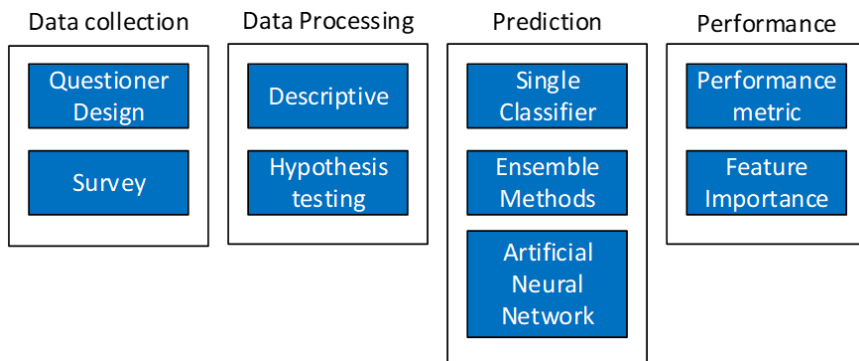


Figure 3: Proposed Methodology for Evaluating Learning in Pancasila through Interactive Comics

Data Collection

The data were collected through a survey using Google Forms involving first-year Petra Christian University (PCU) students who studied Pancasila through interactive comics. The questionnaire consisted of two parts. The first part asked about the respondents' background, including their gender, GPA, living situation, and major (Smiderle et al. 2020; Jia et al. 2016; Denden et al. 2017; Zainuddin et al. 2020; Camingue, Melcer, and Carstensdottir 2020). The second part asked about their learning characteristics: preferred reading material (e.g., comics, eBooks, novels, magazines) and average reading duration (Abid et al. 2023).

In addition, the participant's response to learning Pancasila through interactive comics was measured through the following five questions (Rajabalee and Santally 2021; Appleton and Silbergitt 2019):

- Q1. I generally find the material...
- Detailed: Every detail can be followed and understood easily.
 - Unclear: Some sentences need to be shorter and clearer.
 - Confusing: Overall, sentences are too long and confusing.
- Q2. Studying Pancasila through interactive comics helps me understand the material.
- I can understand the material more easily.
 - It is fairly easy to understand the material.
 - Interactive comics have had no significant impact.
- Q3. I understand faster when studying Pancasila through interactive comics.
- Agree: I understand faster than with conventional methods.
 - No difference: There is no significant difference between learning with interactive comics and conventional methods.
 - Disagree: It takes longer to understand Pancasila through interactive comics.
- Q4. Preference for interactive comics or conventional methods:
- Conventional 1: Conventional learning is much more enjoyable because I am comfortable with this method.
 - Conventional 2: Conventional learning is more interesting because it does not depend on the quality of the Internet.
 - Comic 1: Interactive comics are more interesting because they are more up-to-date and fun.
 - Comic 2: Interactive comics are not very interesting but still superior to traditional methods.
- Q5. Would you recommend learning through interactive comics to your peers?
- Yes: because learning through interactive comics is exciting.
 - No: I would recommend it if the content in the interactive comics improved.

The final section included an open-ended question, asking for criticism and suggestions for improvement.

Data Description and Hypothesis Testing

The data were presented in the form of descriptive statistics. The hypothesis testing was conducted using the Pearson chi-square test for independence. The independence test was carried out between the variables indicating student characteristics (gender, GPA, preferred reading material, and duration of reading) and their responses to studying Pancasila through interactive comics. For example:

Ho: There is no relationship between gender and a student's ability to follow the Pancasila learning materials.

H1: There is a relationship between gender and a student's ability to follow the Pancasila learning materials.

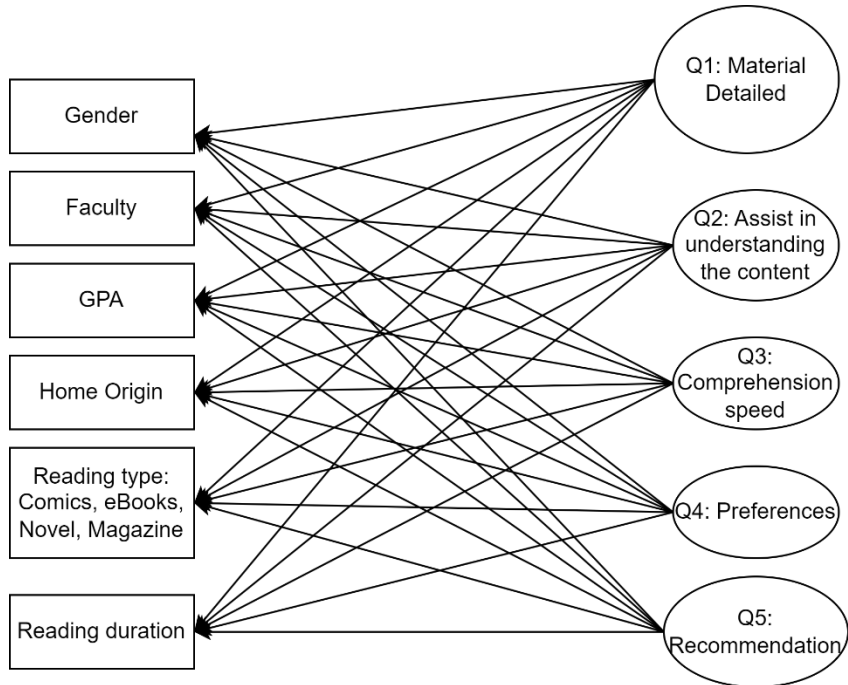


Figure 4: Conceptual Model

Classification

In the final question, we asked the students if they would recommend learning through interactive comics to their peers. We also wanted to know which variables had a strong influence on their decision. To do so, we first modeled the recommendation decision using classification methods. In this study, three major categorizations of classification methods were used: the decision tree as a single classifier; Random Forest, Gradient Boosting, and AdaBoost as ensemble methods; and artificial neural network (ANN) to get the optimal outcome (Géron 2019).

A decision tree is a widely used machine learning technique that is applied to tasks involving classification and regression. The structure resembles a tree, with interior nodes denoting features, branches representing decision rules, and leaf nodes indicating outcomes or class labels. However, decision trees may become unstable due to minor data changes, resulting in varying tree architectures and being susceptible to overfitting, particularly when tree depth is not adequately managed.

Random Forest addresses decision trees' tendency to overfit to their training data. Random Forest is an ensemble learning method that is based on decision trees. It functions by generating many decision trees during the training process and then provides the most frequent class among the classes for classification tasks or the average forecast of the various trees for regression tasks.

Gradient Boosting is an ensemble learning technique that has similarities with Random Forest. It generates a robust predictive model by combining the forecasts of many less effective models. Gradient Boosting constructs trees sequentially, with each tree learning from and fixing the errors of the previous ones, unlike Random Forest where trees are built independently. AdaBoost, like Gradient Boosting, focuses on adjusting the weights of observations to emphasize difficult instances during training.

The last machine learning method employed in this study is artificial neural networks. Artificial Neural Networks (ANNs) are machine learning models that draw inspiration from the biological neural networks seen in the human brain. The system is made up of linked nodes known as neurons or units, arranged in layers. Feedforward neural networks are a typical form of artificial neural network used for classification problems. They are composed of an input layer, one or more hidden layers, and an output layer. A major limitation of artificial neural networks (ANN) is the challenge in interpreting findings. ANN is considered a black box model.

Performance Metrics

Since the students' responses for the willingness to give recommendation is only yes or no, we will have binary classification. The metric used in this study is based on the confusion matrix which is defined as follows (Géron 2019):

Table 2: Confusion Matrix

		<i>Actual</i>	
		Positive	Negative
Predicted	Positive	True Positive (TP)	False Positive (FP)
	Negative	False Negative (FN)	True Negative (TN)

The performance metrics used in this study are:

Accuracy measures the number of predictions that are correct as a percentage of the total number of predictions that are made.

$$\text{Accuracy (CA)} = (\text{TP} + \text{TN}) / (\text{TP} + \text{FP} + \text{FN} + \text{TN})$$

Precision measures the percentage of truly positive from the total predicted positive output.

$$\text{Precision} = \text{TP} / ((\text{TP} + \text{FP}))$$

Recall is also called the True Positive Rate (TPR) measures the percentage of truly positive from the total actual positive output.

$$\text{Recall} = \text{TP} / ((\text{TP} + \text{FN}))$$

F1Score is the harmonic mean of the Precision and Recall

$$\text{F1 score} = (2 * (\text{Precision} * \text{Recall})) / ((\text{Precision} + \text{Recall}))$$

False Positive Rate (FRR) measures the percentage of false positive from the total actual negative output.

$$\text{FPR} = \text{FP} / (\text{FP} + \text{TN})$$

ROC –Receiver Operating Curve plots the Recall vs. FPR at different classification thresholds.

AUC – Area Under ROC Curve measures the entire two-dimensional area underneath the entire ROC curve. An overall measure of performance across all potential classification criteria is provided by AUC.

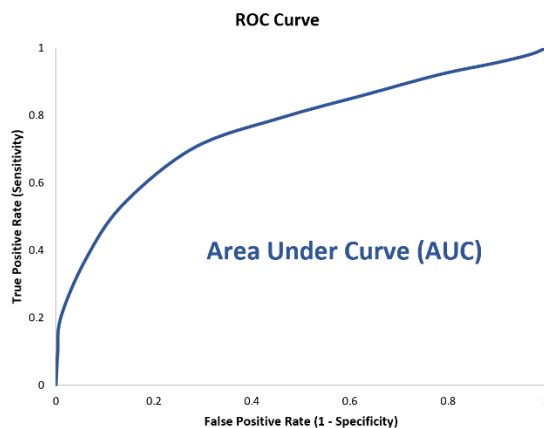


Figure 5: ROC Curve

Results and Discussion

This section discusses the findings of the analysis and provides a summary of the methodology. The first section presents the results of the exploratory data analysis; this is followed by a discussion of the independence and hypothesis tests and the predictions based on the aforementioned classification methods.

Exploratory Data Analysis

The survey was distributed one month after the students finished the Pancasila course and received 145 responses. The composition of male and female respondents was balanced. Most (61.76%) were from the class of 2022. A plurality of the respondents was from Surabaya, the capital of East Java—the second largest city in Indonesia after Jakarta, and the home of PCU. Nearly half had a cumulative grade point average higher than 3.5 (46.08%). The survey also asked whether the students were staying with their families or in boarding houses. Nearly 90 percent of the students' majors were from the Faculty of Industrial Technology, Humanities and Creative Industries, and School of Business and Management (see Table 2).

Table 2: Respondent Background

<i>Respondent Background</i>		<i>Percent</i>
<i>Gender</i>	Male	50.98%
	Female	49.02%
<i>Faculty</i>	IT (Industrial Technology)	31.37%
	HCI (Humanities and Creative Industries)	31.37%
	SBM (School of Business and Management)	25.49%
	CEP (Civil Engineering and Planning)	7.84%
	TE (Teacher Education)	3.92%
<i>GPA</i>	> 3.5	46.08%
	3–3.5	41.18%
	2–2.99	12.75%
<i>Batch</i>	2019	6.86%
	2020	17.65%
	2021	13.73%
	2022	61.76%
<i>Home Origin</i>	Surabaya	49.02%
	Java Island (Excluding Surabaya)	26.47%
	Outside of Java Island	24.51%

Reading Habits

The respondents read comics (33%), eBooks (26%), and novels (25%). Other reading materials, including magazines, were less popular (Figure 6). Most respondents (38.24%) read for one to three hours (Figure 7).



Figure 6: Reading Types Distribution

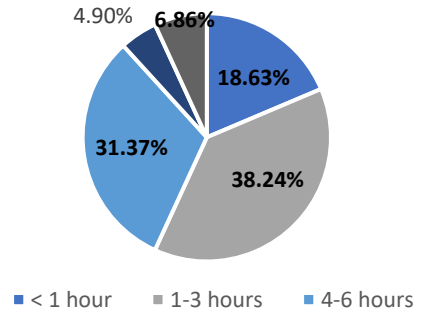


Figure 7: Time for Reading Distribution

The gender distribution illustrated that male students read comics and magazines more than female students, while female students preferred novels or eBooks (Figure 8a). Proportionally, comic reading was preferred by all groups when students were grouped by GPA (Figure 8b).

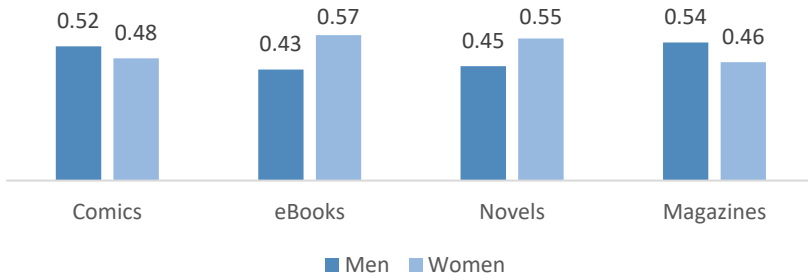


Figure 8a: Reading Types vs. Gender

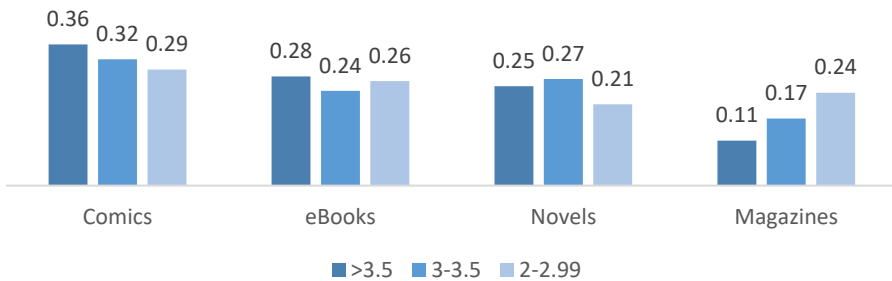


Figure 8b: Reading Types vs. GPA

Figure 8: Reading Types Distribution vs. (a) Gender and (b) GPA

Studying with Interactive Comics

In response to the first question, 73 percent of the respondents said they could understand the content in detail, while 27 percent stated that the material was somewhat unclear. No students said they were entirely confused. The respondents also stated that delivering material through interactive comics helped them learn (48%), while 47 percent said that it was somewhat helpful. Only 5 percent stated that it was not very helpful. Four of these students were male and one was female. All respondents in this latter group had a GPA above 3.0 and liked comics and novels. Most respondents understood the content quickly (67.65%), found interactive comics more interesting, up-to-date, and fun than conventional methods (71.57%), and would recommend them to their peers (see Table 3).

Table 3: Response to Learning Pancasila through Interactive Comics

Response to Learning Pancasila through Interactive Comics		Number of Responses (Percent)
I generally find the material... (Q1)	Detailed	74 (72.55%)
	Unclear	28 (27.45%)
Studying Pancasila through interactive comics helps me understand the material (Q2)	Yes	49 (48.04%)
	Fair	48 (47.06%)
	No	5 (4.90%)
I understand faster when studying Pancasila through interactive comics (Q3)	Yes	69 (67.65%)
	Fair	28 (27.45%)
	No	5 (4.90%)
Preference for interactive comics or conventional methods (Q4)	Conventional 1	4 (3.92%)
	Conventional 2	7 (6.86%)
	Comics 1	73 (71.57%)
	Comics 2	18 (17.65%)
Would you recommend learning through interactive comics to your peers? (Q5)	Yes	64 (62.75%)
	No	38 (37.25%)

Hypothesis Testing

The interdependence hypothesis tests were conducted for all variables indicating student characteristics and their response to studying Pancasila through interactive comics. Two example hypotheses (with gender as the variable) were presented in Section 3.2. The chi-square test for these examples produced a P-value = 0.59 (see Table 4), which fails to reject H_0 . This statement means that there is no relationship between gender and a student's ability to keep up with the class. In general, the hypotheses can be written as follows:

H_0 : There is no relationship between student characteristics and their response to studying Pancasila through interactive comics

H_1 : There is a relationship between student characteristics and their response to studying Pancasila through interactive comics.

Table 4 summarizes the overall P-values of the Pearson chi-square test for all the variables indicating student characteristics and their response to learning Pancasila through interactive comics.

Table 4: Chi-square test P-value between the Variables Indicating Student Characteristics to the Response of Learning Pancasila through Interactive Comics

Features	Q1	Q2	Q3	Q4	Q5
Gender	0.59	0.32	0.45	0.95	0.96
Faculty	0.26	0.57	0.79	0.009*	0.99
GPA	0.79	0.20	0.33	0.62	0.16
Home Origin	0.59	0.19	0.60	0.19	0.90
Comics	0.59	0.16	0.94	0.51	0.04*
eBooks	0.86	0.26	0.06**	0.48	0.64
Novel	0.87	0.03*	0.60	0.30	1.00
Magazine	0.79	0.39	0.60	0.46	0.73
Reading Duration	0.44	0.71	0.51	0.14	0.48

Note: *significant level 5 percent; ** significant level 10 percent

According to Table 4, all students were able to study Pancasila successfully regardless of gender, GPA, living situation, reading preferences, and reading duration. Students’ majors had little impact on learning outcomes, but it did influence the likelihood of claiming that interactive comics are more interesting, up-to-date, and fun than conventional methods (P-value = 0.009; see Figure 9). The students who read comics strongly recommended studying Pancasila through interactive comics (P-value = 0.04; see Figure 10); students who enjoy reading eBooks understood Pancasila faster through interactive comics (P-value = 0.06; see Figure 11); and reading novels was significantly correlated with finding interactive comics helpful (P-value = 0.03; see Figure 12).

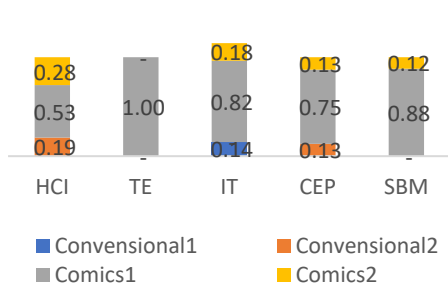


Figure 9: Faculty vs. Comic Preference

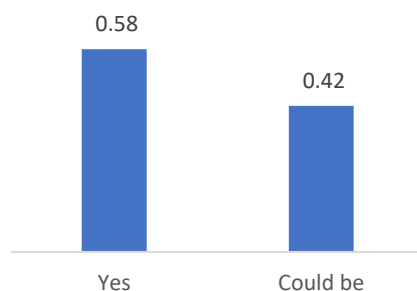


Figure 10: Reading Comics vs. Recommendation

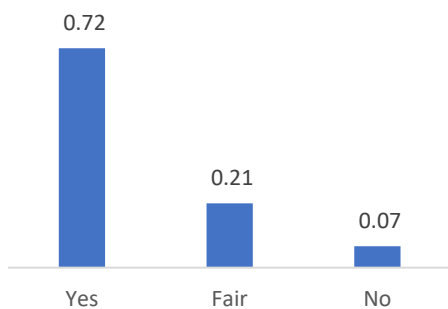


Figure 11: Reading eBooks vs. I Can Understand Faster

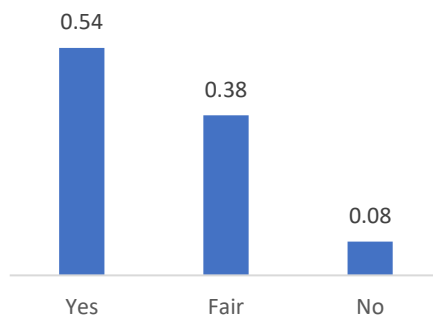


Figure 12: Reading Novel vs. It Helps Me to Study Pancasila

Gamification improves learning outcomes by effectively engaging and motivating students to study. Game components like points, levels, badges, and leaderboards enhance the learning experience for students, increasing their motivation to spend more time engaging with the topic. Gamification enhances active learning by providing students with a hands-on experience, leading to a deeper knowledge of the content compared to traditional techniques. Another advantage of gamification is prompt feedback. Students can pinpoint areas that need development and make corrections. Feedback enables ongoing learning and allows students to monitor their progress over time.

Gamification assists in tailoring learning experiences to the individual requirements and preferences of each student. Personalization guarantees that each student is provided with the necessary support and challenges to achieve success. Gamification fosters collaboration and social contact among students, enabling them to learn from one another and cultivate essential collaborative skills. Finally, Gamification can narrow the divide between academic understanding and practical application by replicating genuine scenarios and problems.

Student Recommendations

This section examines the characteristics that affected whether respondents would recommend using interactive comics to learn Pancasila. We used machine learning classification methods (e.g., decision tree, Random Forest, artificial neural network, adaBoost, and Stochastic Gradient Boosting) to classify their degree of willingness. The computational work was carried out using Orange 3.35. The data testing using the cross-validation technique with five folds showed that the AUC of Random Forest outperformed the other four proposed methods in predicting students' recommendations. Additionally, feature importance showed that recognizing that interactive comics are helpful had the greatest effect on the model (Bouchlaghem, Akhiat, and Amjad 2022). The second-highest score was stating that interactive comics helped them understand Pancasila faster. Figure 13 exhibits the detailed scores.

Table 5: The Machine Learning Performance Measurement

Model	AUC	CA	F1	Precision	Recall
Tree	0.596	0.593	0.582	0.577	0.593
Random Forest	0.741	0.637	0.618	0.619	0.637
ANN	0.684	0.659	0.656	0.654	0.659
AdaBoost	0.661	0.604	0.602	0.600	0.604
SGD	0.680	0.703	0.702	0.702	0.703

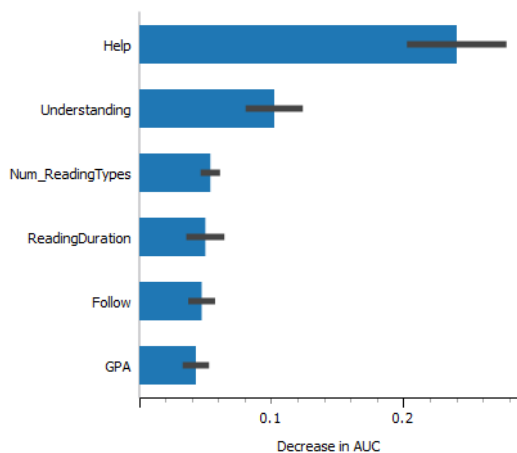


Figure 13: Feature Importance of Students Recommend Learning Pancasila through Interactive Comics

Criticism and Suggestions

Accessing Petraverse via smartphones was challenging. In addition, the clarity of sound and intonation could be improved. Slow loading times and screen lag are evident issues. It would be beneficial to include a button for turning off the music. To enhance the user experience, the following improvements could be made: optimizing smartphone access, refining sound quality and intonation, addressing loading speed and lag, and introducing a dedicated mute button.

In addition, the vocabulary and intonation come across as overly formal. The text in the comics is too small, affecting readability. There is room for expansion in terms of gaming modes. Moreover, the animations remain limited and sluggish, which affects the overall experience. Incorporating a greater variety of characters into Petraverse modules could enhance the content. To improve these issues, the developers could consider revising vocabulary and intonation to be more natural, increasing the text size, diversifying gaming modes, refining animations for smoother performance, and introducing a more comprehensive array of characters.

The Petraverse login process should be simplified for user convenience. The responsiveness of the website should be improved to ensure a smooth experience on all devices. Enhancements are suggested for the animation scenes, aiming for smoothness and variety. Accordingly, the developers could continue refining the login process, expand on features like progress-saving, maintain the website's responsiveness, and create seamless and diverse animation scenes.

Student engagement must be sustained through interactive assessments integrated inside the comic, which is where gamification occurs. The assessment module evaluates the learning objectives and students' accomplishments. Interactive comics are effective for philosophical topics such as Pancasila or religion, while Petaverse also offers technical lessons on VR technology. This VR technology subject is popular among not just engineering students but also students from other majors. Engaging narratives, animations, and voiceovers make interactive comics attractive to Generation Z students (Sayılğan 2023).

Conclusion

This study evaluated studying Pancasila through interactive comics. Most of the respondents (72.55%) said they understood the material in detail, that interactive comics helped them learn (48.04%), that they were easy to understand (67.65%), that they were more interesting than conventional methods, and that they would recommend using interactive comics as a medium to study Pancasila (62.75%).

In addition, students' backgrounds (i.e., gender, GPA, living situation, major) did not affect their level of understanding, nor did their reading preferences or average reading duration. However, students' majors did impact their likelihood to indicate that interactive comics are more interesting, up-to-date, and fun than conventional methods. Comic readers were likely to recommend using interactive comics to understand Pancasila. Students who read e-books noted that interactive comics allowed them to grasp the material more quickly than traditional learning.

Additionally, the study discovered that 62.75 percent of students would advise their peers to learn Pancasila using interactive comics. Since Random Forest had the highest AUC, it was chosen to classify students' willingness to recommend using interactive comics to study Pancasila. Finally, the feature important analysis demonstrated that recognizing that interactive comics are helpful for learning and that they speed up comprehension had the greatest impact on the model.

However, Petaverse has room for technical improvements. To make the interface more navigable for learners, improvements should be made to the sound, voice, image, and text. Additionally, the animation needs improvement to facilitate gamification. Future research could investigate these suggestions and how they can best be implemented.

AI Acknowledgment

The authors acknowledge the use of Quillbot (<https://quillbot.com/paraphrasing-tool>) and Grammarly (<https://grammarly.com/>) to paraphrase and grammar check. No prompts were used in Quillbot and Grammarly. The output from these AI tools was used to clarify the meaning of the sentences. The first manuscript was professionally proofread, but in the revised version, we used Quillbot and Grammarly to help paraphrase and grammar check.

Informed Consent

The authors have obtained informed consent from all participants.

Conflict of Interest

The authors declare that there is no conflict of interest.

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