Kashihara, A. et al. (Eds.) (2024). Proceedings of the 32nd International Conference on Computers in Education. Asia-Pacific Society for Computers in Education

Analyzing Student Behavior in Viat-map: Steps and Time as Performance Indicators

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Abstract: Number of steps and time duration needed while solving the problem can be considered as a representative of student's learning behavior and their effort of understanding. Learning Analytics is a process for monitoring students' thinking process and can become strong evidence to support teachers' objectives in class. Viat-map is an application that implements the Toulmin Argument method and reconstruction approach. It will assist students to think logically by following the teacher's logic, and it shows a positive contribution in the learning process. The reconstruction process used in Viat-map also offers immediate evaluation of student's mistakes. However, a challenge arises in the Viat-map's evaluation of the student's learning process, as the reconstruction process requires students to have the correct answer to complete the learning process. Having this way, new approaches in using student's behavior as learning process score (Viat-map score) are offered. This study involved 105 Students divided into 58 students from the previous research (2023) and 47 students to confirm the Viat-map score (2024). K-Means clustering was chosen for its ability to perform unsupervised clustering, ANOVA was used for comparing more than two groups, and Pearson Correlation was used to examine the relationship between two sets of data. The results suggest that the number of steps taken and the time spent in the learning process can be considered positive indicators of student behavior in the learning process.

Keywords: K-Means, Toulmin Argument, Viat-map, Learning Analytics

1. Introduction

The term Learning Analytics refers to the process of measuring, collecting, analyzing, and delivering information related to learners in terms of understanding and optimizing learning (Yusuf et al., 2023). Learning Analytics can be used in predicting the extent of student understanding and can be used by educators in decision making and further analysis regarding the resource utilization and student achievement (Sweta et al., 2021). In the context of learning, two important cognitive aspects that affect the learning process are cognitive load and logical thinking. Students often experience cognitive load related to the use of their working memory during the learning process (Cunff et al., 2024). When a lot of new information enters and exceeds the capacity of working memory, the information will not enter the long-term memory and interfere with students' academic abilities (Tzafilkou et al., 2021). On the other hand, logical thinking is the cognitive ability to apply systematic reasoning and facts in solving problems (Punia et al., 2022). Teaching argumentation as a component of developing logical thinking has been shown to be an effective method for enhancing student's thinking quality (Al-Ajmi & Ambusaidi, 2022).

One interesting approach in teaching argumentation is the Toulmin Argument method, which emphasizes three components as the foundation of an argument, namely, Claim, Grounds, Warrant (Majidi et al., 2021). The implementation of Toulmin Argument in an educational context can improve students' understanding and encourage them to think more critically and innovatively (Magalhães, 2020). Viat-map, an application that utilizes the concept

of Toulmin Argument, is a clear example of how technology can be used to improve students' learning experience (Andoko, Amalia, et al., 2023; Rismanto et al., 2021).

There are phenomena that can hinder the learning process, such as gaming the system. This behavior involves students' attempts to achieve good results by exploiting the system's weaknesses rather than deeply understanding the material (Baker et al., 2006). Confusion and lack of motivation are the driving factors behind this behavior (Rodrigo et al., 2007). This shows how important it is to pay attention to student skills as well as aspects of motivation and meta-cognition in the learning process (Baker et al., 2013).

The motivation for this study was to identify student behavior when using the Viat-map application and creating a new evaluation method for the students. To answer the motivation, several research questions need to be answer, they are:

1. What specific student behaviors can be identified using Viat-map?
2. Can Viat-MAP scores be used to evaluate students' understanding processes based on their behaviors?

In this study, several stages were carried out to answer the research question as well as to deepen student behavior. Previous studies revealed that there are certain behaviors performed by students in quizzing based on certain activities (Juhaňák et al., 2019). This underlies our assumption of the existence of certain behaviors performed by students when completing exercises on the Viat-map application. Analyzing student logs that represent student behavior in doing the exercises is one of the main steps in this research. The analysis is carried out to obtain information that is useful in determining the behavior group of each student. Experimental tests will be carried out to justify the assumption that these behaviors have an influence on the achievement of grades and understanding obtained by students.

2. Literature Review and Related Research

2.1 Cognitive Load

During the learning process, students often face cognitive challenges called cognitive load. Cognitive loads have 3 types, namely intrinsic load, extrinsic load, and germane load. Task complexity and knowledge can influence intrinsic load, non-learning-supporting instructional components influence extrinsic load and learning-supporting instructional components influence germane load (Leppink et al., 2013). According to other studies, the amount and intensity of information interaction between tasks and subjects has a relationship with cognitive load. This theory provides a general basis for describing and predicting how learning methods and materials can affect learners' working memory usage (Wang et al., 2020). Therefore, building learning strategies is important to minimize students' working memory load and promote more effective learning (Cunff et al., 2024).

2.2 Student Behavior

Student behavior is the actions and behavior of students in the learning environment. There are several student behaviors that may occur. Some of them are guessing behavior, gaming the system, help-seeking behavior, and willingness to collaborate (Waspada et al., 2019). The identification of several student behaviors in the learning system is a major concern because it has an important role in student evaluation, especially in the context of student assessment (Juhaňák et al., 2019).

2.3 Toulmin Argument

Toulmin Argument is an argumentation method developed by philosopher Stephen Toulmin with six components in it. The six components are then divided into two groups, namely the primary group which contains claim, ground, and warrant. Meanwhile, the second group is the secondary group which contains rebuttal, qualifier, and backing. The components in the

primary group are the main components as well as the foundation of an argument (Majidi et al., 2021). Claim is the main statement to be conveyed, ground is a fact that supports the claim, and warrant is a sentence that explains why the ground supports the claim. Toulmin itself is the most complete argument model that can foster, train, and develop students' critical thinking skills (Andoko et al., 2022). Therefore, Toulmin Argument can be considered as a constructive teaching method in developing students' argumentation skills (Magalhães, 2020).

2.4 Viat-map

Viat-map was introduced as a system that implements Toulmin's argument in it (Andoko et al., 2022) as an effort to improve reading comprehension in English language learning (Andoko et al., 2023). Viat-map applies a closed-based application concept where students are not allowed to create their own answers. Students can only choose answers that have been provided to form an argument (Andoko, Asri, et al., 2022). According to (Andoko, Amalia, et al., 2023) the Viat-map application has three main phases:

1. Teacher's logical map: This phase is where the teacher creates an exercise by listing the claims that are the main points that a text is trying to convey. To support the claim, the teacher adds one correct ground and warrant each. In addition, the teacher will prepare two incorrect grounds and two warrants as a variation of the exercise.
2. Learner's working space: The next phase is the phase for students to answer the exercise questions that have been created by the teacher. Students will be asked to choose which ground and warrant are correct from those previously prepared to support the given claim. Students will not be able to move to another exercise problem if they have not successfully solved the exercise problem that has been prepared.
3. Overlapping analysis: This phase can be used by the teacher when looking for information on the number of student errors based on the numbers in each answer row. There are two different numbers, the first number represents the number of errors made by the student and the second number represents how many students made errors. More information about the student and the number of errors can be obtained when the teacher selects the row.

2.5 Gaming The System

Gaming the system is referred to as the behavior of students in educational settings who seek to succeed in a way that instead of thinking about the material and using knowledge, they choose to exploit the characteristics of a system (R. S. J. D. Baker et al., 2006). There are several student behaviors that are classified as gaming the system, which are when students ask for help quickly and repeatedly and students enter a series of answer attempts quickly and systematically. Dislike of subject matter that uses software and lack of independent encouragement can cause students to tend to act gaming the system (R. Baker et al., 2008). Confusion when doing exercises is also a contributing factor to the behavior (Rodrigo et al., 2007). Gaming the system has an impact on meta-cognition and motivation (Furtado et al., 2019). This "*gaming the system"* behavior often leads to poorer learning. The act of gaming the system performed by students indicates the students have poor meta-cognition and lack of motivation (R. S. J. D. Baker et al., 2013).

3. Method

3.1 K-Means Clustering

K Means clustering was used to create groups of students based on their behavior when using the system. Since this research doesn't have any ground truth for the groups, choosing K Means allows us to discover a hidden structure of the data. However, it will bring more challenge to define the label for each cluster. During the learning process, Viat-map recorded

each activity made by the students. One of the activities that was recorded is the steps. It will create a new record for every chosen answer made by the students and record the created time. Having those conditions, we can calculate the number of steps taken by the students and the duration needed to finish an exercise. Each student will have their own steps and time.

The data that will be used for clustering came from a previous experiment (Andoko, Asmara, et al., 2023), that involved 58 students. This research is using https://www.statskingdom.com/cluster-analysis.html to calculate K Means. The parameter that was used are:

1. Cluster: 0 – automatic
2. Scaling: Standardized
3. Repeats: 20

3.2 Experimental Setting

This study involved a hundred and five students in total. All the students are Indonesian students who used English as Foreign Language. Throughout the entire study, the teacher did not provide any feedback or explanations regarding the reading material, or the mistakes made by the students. This activity consists of two activities and experiments from a different time frame by using the same materials and the same level of students. The first experiment conducted in 2023, where the result is showing a positive result in using Viat-map(Andoko, Asmara, et al., 2023). From this study, fifty-eight students' log data were used to create clusters of student's behavior based on the time consumption and steps taken while using the Viat-map. After forming the clusters, the post-test results of the students in each group were aggregated. This aggregation was intended to differentiate the students' achievements and label their behavior in each cluster. This label will be assigned a score to evaluate their behavior (Viat-map score) while using the application.

The second experiment took place in 2024 and involved forty-seven sophomore students from two Information Engineering classes at the State Polytechnic of Malang. This experiment introduced a new feature called the Viat-map score and examined its relationship with post-test scores. The experiment lasted three weeks: the first two weeks were used to assess basic English skills and introduce the Toulmin Argument concept and Viat-map, while the third week was the actual experiment. During this week, students followed a designated experiment design (Figure 1). Both pre-tests and post-tests were administered using the same test, but students did not receive their scores or evaluations.

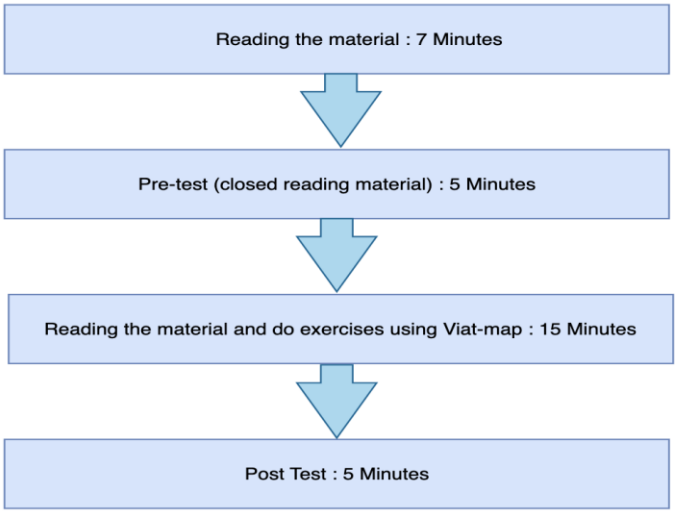


Figure 1. Experimental Design

3.3 Measurement and Analysis

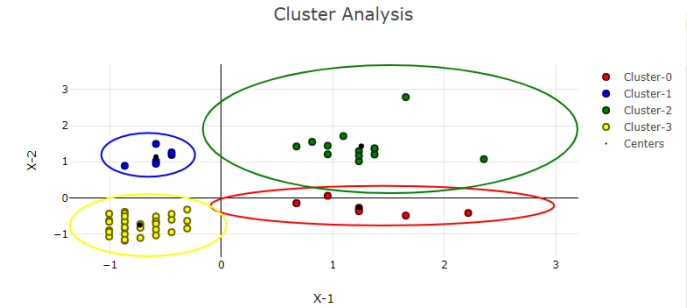
The post-test consisted of ten multiple-choice questions, each with the same difficulty level. Each correct answer was awarded 10 points, while incorrect answers received 0 points. The

total score was the sum of all correct answers. K-Means clustering was used to group students based on their steps and time. ANOVA statistical analysis, along with Bonferroni and Holm's post-hoc tests, was employed to measure the post-test scores of the created clusters and to identify score differences between them. Finally, Pearson correlation was used to examine the relationship between post-test scores and Viat-map scores.

4. Result

4.1 Log Data Analysis from 2023 Experiment
4.1.1 K-Means Analysis

The results section is divided into three parts for a comprehensive analysis. The first part focuses on identifying the behaviors of students with the lowest performance within the groups or clusters defined by K-Means clustering. The K-Means clustering analysis resulted in four distinct clusters. (Figure 2).



Cluster Centers

Cluster	X-1	X-2
0	1.2341	-0.2648
1	-0.5869	1.1317
2	1.2557	1.4317
3	-0.7315	-0.7511

Figure 2. K-means Cluster Analysis

The students in each cluster will be paired with their post-test scores. The main purpose is to determine whether there are any differences between each cluster and to label each created cluster. Based on the results (Table 1), we found that there are two clusters with minimal performance, consisting of a small number of students: Cluster Zero (C0) and Cluster One (C1). Cluster Zero aligns with the behavior of "Gaming the System," where students tend to find the answer by combining any possible answers, resulting in a high number of steps and a low amount of time. In contrast, Cluster One has a minimal number of steps but a high amount of time.

Table 1. *Cluster Result and Its Average Steps and Time*

Clusters	Average Steps	Average Time	Average score	Number of Students
C0	8	74.1667	50	8
C1	3.66	147.0556	40	6
C2	8.051	162.7179	60	13
C3	3.32	48.7849	70	31

Descriptive statistic and ANOVA statistical analysis conducted to investigate the post-test difference between clustered groups. Descriptive statistical analysis shows the variance between groups is in moderate variation since the number of students between groups are different (Table 2). The result for ANOVA (Table 3) suggested that there are significant differences between posttest in clusters ($p = .0001$; $p < .001$), however a post-hoc analysis using Bonferroni and Holms (Table 4) is required to find out which clusters are different. The

result suggests that C1<C2, C1<C3, and C0 < C3. These results show that C3 is the highest followed by C2, C0, and C1. Because C3 was higher than C1 and C0 while C2 was only higher than C0, C0 was less than C3 while C1 was less than C2 and C3 (C3 > C2 > C0 > C1). Based on this result, all the cluster has a different characteristic and post-test score.

Table 2. *Descriptive Statistic for Clusters*

Treatment →	C1	C0	C2	C3	Pooled Total
Observations N	6	8	13	31	58
Sum ∑xi∑xi	25.0000	43.0000	82.0000	211.0000	361.0000
Mean ¯x$\bar{x}$	4.1667	5.3750	6.3077	6.8065	6.2241
Sum of squares ∑x2i∑$xi2$	117.0000	237.0000	532.0000	1,493.0000	2,379.0000
Sample variance s2$s2$	2.5667	0.8393	1.2308	1.8946	2.3173
Sample std. dev. ss	1.6021	0.9161	1.1094	1.3765	1.5223
Std. dev. of mean SE¯x$SE\bar{x}$	0.6540	0.3239	0.3077	0.2472	0.1999

Table 3. *ANOVA Statistical Analysis for Clusters*

source	SS	df	MS	F statistic	p-value
treatment	41.7699	3	13.9233	8.3247	0.0001***
error	90.3163	54	1.6725		
total	132.0862	57			

Table 4. *Bonferroni and Holms Post-hoc for Clusters*

treatments pair	Bonferroni and Holm TT-statistic	Bonferroni p-value	Bonferroni inference	Holm p-value	Holm inference
C1 vs C0	1.7300	0.5360076	insignificant	0.2680038	insignificant
C1 vs C2	3.3543	0.0087637	** p<0.01	0.0073031	** p<0.01
C1 vs C3	4.5765	0.0001687	** p<0.01	0.0001687	** p<0.01
C0 vs C2	1.6049	0.6860385	insignificant	0.2286795	insignificant
C0 vs C3	2.7912	0.0434731	* p<0.05	0.0289820	* p<0.05
C2 vs C3	1.1672	1.4896394	insignificant	0.2482732	insignificant

4.1.2 Viat-map Score Evaluation Base Line

Further investigation is required to provide in-depth insight into the characteristics of the C1 and C0 clusters. An interview was conducted to verify the characteristics of the students and to obtain some explanations and confirmations. Below is a list of open-ended questions used to confirm their activity (see Table 5):

Table 5. *List of Questions*

No	Question
1	Do you feel stress understanding the text?
2	Do you try any possible pair to find the answer?
3	Do you failed to understand the text?
4	Do you feel that you cannot finished the task?

In summary, all the students in C1 felt stress and could not finish the task, on the contrary students in C0 did not feel stress and felt able to finish the task by pairing the possible answers. However, both clusters mostly failed to understand the text, especially for C1. Based on that result, this study start offers some labels to justify the learner's behavior's (Figure 3), they are:

1. C0 Label: Gaming the System (Gaming)
   The assumption built from this label is that students tried so many different pairs of the answer that will cause them to have **high** number of steps, however, the time will be **low.** The given Viat-map score is 40 there are some members who failed to understand the text.
2. C1 Label: Struggling
   The assumption built from this label is that students fell stress, mostly failed to understand the text and feel that they cannot finished the task. This clusters identified to have **low** number of steps, however, the time will be **high** because of the thinking process. The given Viat-map score is 20.
3. C2 Label: Normal
   The assumption built from this label is that students will be thinking and make some mistakes to get the correct answer that will cause to have **high** number of steps, however, the time will be **high** because of the thinking process. The given Viat-map score is 60.
4. C3 Label: Ideal
   The assumption built from this label is that students understand the argument and directly find the correct answer that will cause to have **low** number of steps and have a **low** number of times. The given Viat-map score is 80.

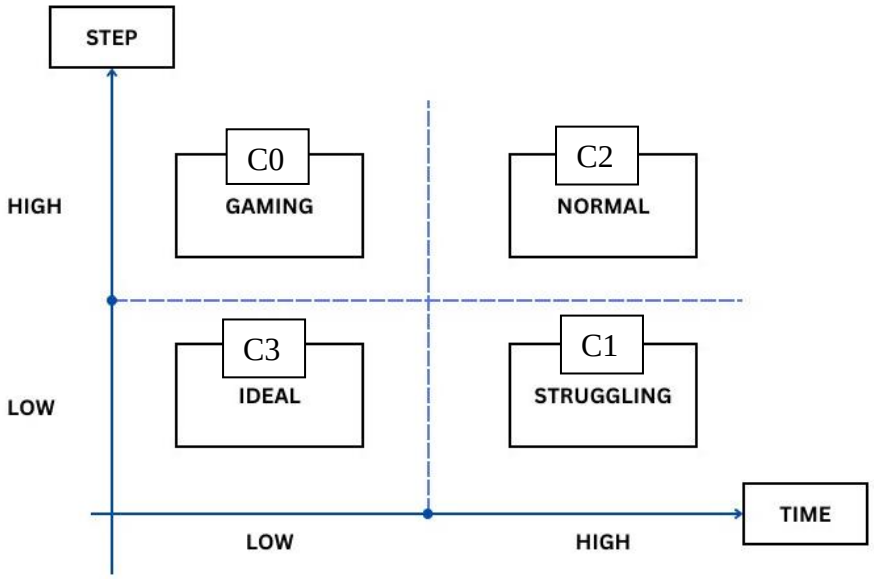


Figure 3. Cluster's Label

4.2 The experiment result in 2024

4.2.1 Correlation Between Post-Test and Viat-map Score

In this section, we delve into the statistical findings based on Pearson Correlation. The analysis was meant to measure the relationship between the Post-Test and Viat-map scores (Table 6). Based on the result, there are several interesting facts found. The Pearson correlation coefficient between the Post-Test and Viat-map scores indicates a moderate positive correlation (0.5251). This positive value of 0.5251 indicates a positive linear correlation, meaning that as one variable increases, the other tends to increase as well. A strong and significant correlation was also found between the Post-Test and Viat-map scores, as indicated by a p-value of .000151, which is less than the significance level of 0.05. Based on the result, there is strong evidence found that both Test is having a relation of moderate and significant (Figure 4).

Table 6. *Pearson Correlation Analysis*

Parameter	Value
Pearson correlation coefficient (r)	**0.5251**
r^2	0.2757
P-value	0.0001511 ***
Covariance	86.8575
Sample size (n)	47
Statistic	4.1386

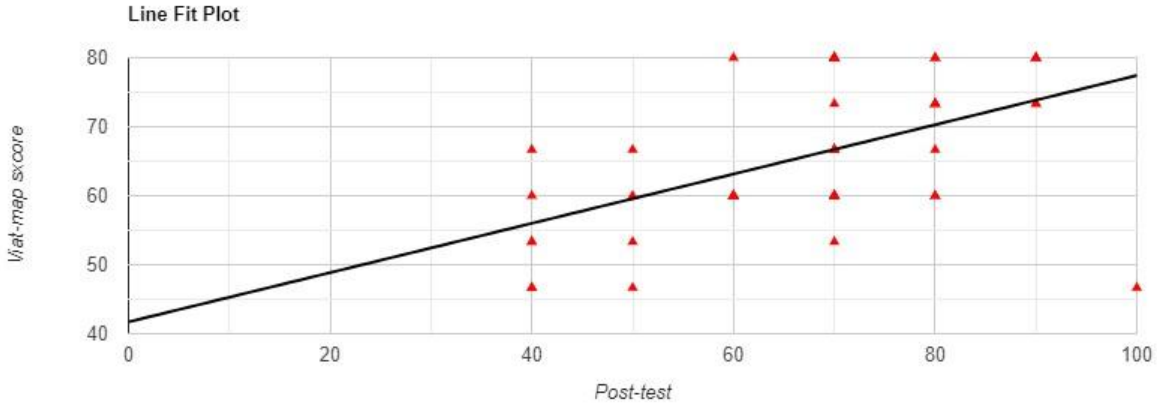


Figure 4. Line fit plot diagram for Post-test and Viat-map score

5. Discussion and Conclusion

Learning behavior during the learning process could bring a huge difference in understanding between students. Viat-map is an application to assist students in the learning process by asking the student to form a Toulmin Argument provided by the Teacher. This application also records the activity made by the student during their activity on constructing the argument. Viat-map basic principle is allowing student to make mistakes and let them to fix the mistakes by them self. Students cannot move to the next exercise until they are able to answer the current exercise correctly. Having this condition is very hard to compare student's answer with the teacher's answer since at the end both answers are correct. However, recording the activities done by the student could be one way to expose and analyze their understanding and offer a new point of view for the teacher to be aware of students' specific behavior.

The first aim of this study is to reveal students' activity based on their behavior while using Viat-map. This study was able to define four groups and gave the label for each group of students' behavior. Based on those groups, this study also suggests some scores to measure the level of understanding for each student while using Viat-map namely Viat-map score.

The second objective of this investigation was to assess students' behavior scores (Viat-map score) compared to their Post-test. Pearson correlation analysis between the Post-Test and Viat-map scores, revealing that a moderate positive correlation (moderate and significant) was found between them (Pearson correlation coefficient = .5251) and a significant correlation (p-value = .0001511). This finding suggests that the analysis of steps and time taken by students during their interaction with Viat-map is a viable indicator of their understanding. For clarity, a line graph was employed to illustrate the Post-Test and Viat-map scores, along with the variation between them (Figure 5).

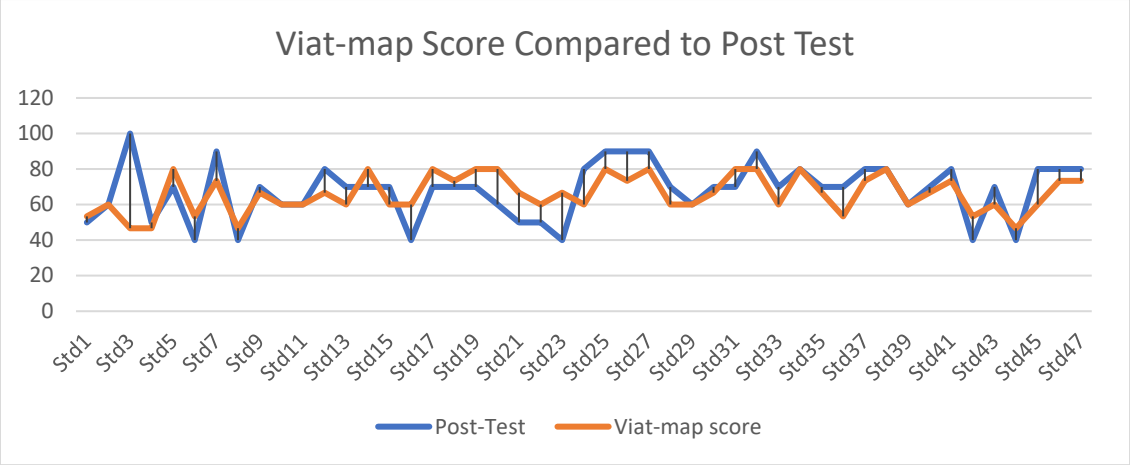


Figure 5. Line Graphical Chart of Viat-map Score and Post-Test

In summary, this study has demonstrated that Viat-map effectively specifies student behavior through their interactions with the application. Consistently, Viat-map supports the learning process within a controlled setting and with restricted application usage. Additionally, the newly introduced Viat-map score to evaluate students' behaviors feature has shown encouraging outcomes. Expanding the analytical framework to include inputs like expressions and emotions could further enhance our understanding of student behavior. To achieve more robust and dependable findings, future research should incorporate a broader participant base to improve the results' reliability and credibility.

Acknowledgements

We would like to thank State Polytechnic of Malang for funding this research under Research grant number: SP DIPA-023.18.2.677606/2024.

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