Flipped Classroom Assisted Autograph in Calculus Learning for Engineering Students: A Rasch Measurement Study

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Abstract: This project aims to investigate the Flipped Classroom Model Assisted Autograph can help engineering students improve their math skills. Many researchers have discussed how the Flipped Classroom Model has been proven successful for online learning usage, particularly during remote learning because of the Covid-19 pandemic's effects. However, the flipped classroom concept has yet to be implemented in conjunction with other supporting learning media. As a result, this project will combine the flipped classroom concept with Autograph media in calculus instruction. This study is an experimental study using a one-group pretest-posttest design. The data was gathered using essay test instruments and motivation questionnaires that were both valid and reliable. Rasch Model Measurement (Stacking Analysis) was employed as part of the data analysis, aided by the Winstep tool. The change in the logit value in each engineering student test results shows that engineering students' mathematics learning achievement improved. The result indicated that students gave positive feedback on the use of Autograph for mathematics after experiencing Flipped Classroom Model. Based on these findings, a Flipped Classroom Model based on Autograph can improve engineering students' mathematics learning achievement.

INTRODUCTION

The development of Information, Communication, and Technology (ICT) in education has brought many changes in the implementation of educational programs - covering educational curriculum, learning methods, to students' evaluation – which have been the results of the Covid-19 pandemic situation. The transformation of the learning process requires the integration of technology so that learning objectives and achievements can still be obtained optimally. Changes in the implementation of the learning process are supported by the direction of higher education curriculum policies that have flexibility in learning programs. The flexibility provided refers to the application of technology in the learning process. Junaidi et al. (2020) explained that changes in the implementation of learning process at higher education level can take advantage of a learning model that supports distance learning that is integrated with technology (e-learning), namely the flipped classroom model. Online learning is not merely caused by the Covid-19 pandemic, but also the demands of the digital era as well as the Industrial Revolution 4.0 towards Society 5.0. The

Industrial Revolution 4.0 demands technological developments integrated into the process of implementing education. The higher education based on Industrial Revolution 4.0 ensures that the learning process that is transformed from face-to-face to online-based learning (e-learning) does not affect the quality of the educational program. Sumantri et al. (2020) explained that changes in the implementation of the learning process can be utilized as part of improving the competence and quality of educational programs that integrate implementation procedures through technology. The existence of real classes is slowly being replaced with virtual classes assisted by various learning platforms available, as well as those developed by each higher education institution based on the Learning Management System. In addition, the implementation of online learning is also supported by the application of the flipped classroom model.

The definition of the *flipped classroom model* varies in the literature. Several studies explained that the flipped classroom model is a learning model that has two conditions, where students prepare learning materials before the class starts (e.g. watching lecture videos) and follow the learning process in real classes (such as applying problem-solving skills to assignments and structured discussions) (Bachiller & Badía, 2020; Lo & Hew, 2017). Another study explained that the application of the flipped classroom model is identical to combining two learning models, namely face-to-face learning models and online-based learning models by integrating technology (Lo et al., 2017; Ramadhani, 2020; Ramadhani & Fitri, 2020). Several previous studies implemented the flipped classroom model in the learning process before the Covid-19 pandemic and evaluated the integration of the model. The results show that the integration of the flipped classroom model is an active learning strategy that can improve students' learning experiences (Crosier et al., 2000; Herreid & Schiller, 2013; Meyers & Jones, 1993; Siegle et al., 2013) and is more effective than the traditional learning model which are based on lectures and discussions (Baytiyeh, 2017; MoK, 2014). The implementation of the flipped classroom model in learning mathematics in previous studies also showed that students' knowledge, attitudes, and learning achievement in mathematics increased. The flipped classroom model makes the learning process more active and has a positive influence on the student learning environment (Fernández-Martín et al., 2020; Krouss & Lesseig, 2020; Wei et al., 2020). The scheme of flipped classroom model assisted of Autograph in calculus learning cn be seen in Figure 1.

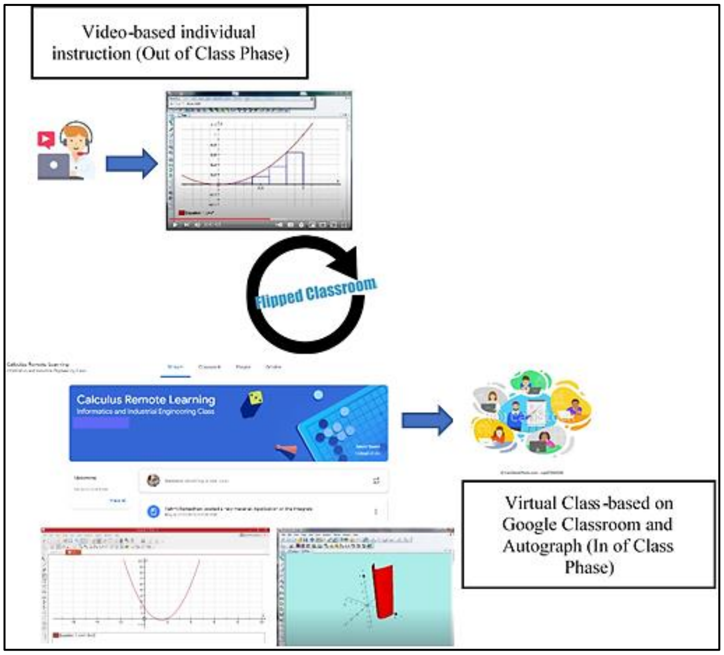


Figure 1: Scheme of Flipped Classroom Model Assisted of Autograph in Calculus Learning

The effectiveness of the flipped classroom model applied during the Covid-19 pandemic situation also contributes positive results in terms of character building, collaboration, communication, critical thinking, and creativity (Latorre-Cosculluela et al., 2021). Learning based on the flipped classroom model attracts students' attention that it can help them improve their performance in during exams. Contrary to Blair et al. (2016) found that no significant increase in terms of student performance and achievement through the flipped classroom model. These findings seem contradictory, but to Tang et al. (2020), effective communication was one of the most important factors in the application of the flipped classroom-based learning. The role of interactive communication built by educators also provides increased motivation and independence of students in participating in a learning process that is far different from previous usual learning experiences. The impression given to students on the implementation of learning based on the flipped classroom model is the first factor that educators need to pay attention to so that the achievement of learning outcomes can be reached successfully. In Attard & Homes (2020), interactive communication between students and teachers supported successful application of the flipped classroom model. Interactive communication also provides opportunities for students to understand their learning styles and gain access to equal learning opportunities that are more in line with student learning needs.

Regardless, the application of the flipped classroom model has not yet been collaborated with other learning support media. Supporting media of technology-based learning provides further convenience for students in exploring mathematics material provided. The application of the flipped classroom model only relies on the Learning Management System (LMS) which contains learning videos that were previously prepared by educators. LMS which contains learning videos has an impact on student satisfaction in acquiring new knowledge as well as student motivation and enthusiasm for learning. Exploration, interest, and creativity of students in developing material content are also limited, which causes the learning process to be centered on educators. Weinhandl et al.(2020a, 2020b) explained that the flipped classroom model can only integrate video or technology in the learning process, but the technology integration discussed is a technology that helps students solve problems, not through direct or direct activities. In addition, Orlando & Attard (2016) added that in the pre-class phase in the flipped classroom model material content transmission is carried out as a source of knowledge as well as training programs that require students to be active and creative in obtaining first knowledge on a material topic before being in the actual class (face-to-face phase). Thus, the flipped classroom model that collaborates with technology-based learning supporting media can facilitate the development of a learning environment and have a positive impact on students related to the findings obtained (Samuelsson, 2006).

One of the supporting media for technology-based mathematics learning that can be collaborated in the application of the flipped classroom model is Autograph. Autograph is one of the dynamic software applications that helps students learn calculus, algebra, and coordinate geometry. Douglas Butler created it to assist students and instructors in visualizing mathematics at the secondary and university levels through dynamically connected objects. In both 2D and 3D, Autograph emphasizes the use of dependent, selectable mathematical objects to assist students in grasping the principles of probability and statistics and coordinate geometry (Isiksal & Askar, 2007). Autograph allows drawing curves (both implicitly and explicitly specified), solving simultaneous equations, and plot derivatives, among other things. It has three modes of operation: 1D for statistics and probability, 2D for graphing, coordinates, transformations, and bivariate data, and 3D for three-dimensional graphing, coordinates, and transformations (Aman et al., 2018; Karnasih & Sinaga, 2015).

In this study, Autograph applied calculus for engineering students. Engineering students study calculus material in the first year of lectures, and several sub-materials require additional visualization as a tool for students to understand the material. The existence of Autograph will provide a lot of convenience in studying calculus consisting of graphs, area problems, to three-dimensional geometry for engineering students. Several previous studies have also shown that Autograph software is useful in terms of improving the effectiveness and quality of teaching and student learning communication (Triana et al., 2019). The use of Autograph software provides convenience in learning mathematics, especially in teaching content related to integral applications in visualization and graphics. Autograph also give the opportunities for students to find the concept of areas with their own, and ultimately improve students' conceptual understanding, mathematical communication, problem-solving, and critical thinking skills (Bina et al., 2021; Ramadhani, 2017). Learning mathematics that requires a lot of interaction, reasoning, and observation requires interactive software, like Autograph (Tarmizi et al., 2009).

Based on the discussion above, the use of Autograph in technology-based learning has not been collaborated in the application of the flipped classroom model, especially in learning mathematics. Therefore, this study aims to implement the flipped classroom model using Autograph in calculus learning for engineering students. The purpose of this study is to assist students in understanding calculus concepts to optimize engineering student mathematics learning achievement. Research questions that will be resolved in this study include:

1. Can the application of the flipped classroom model assisted by Autograph improve the mathematics learning achievement of engineering students-based test scores?
2. How is the motivation to study mathematics for engineering students after being taught using the flipped classroom model assisted by Autograph in learning calculus during the Covid-19 pandemic?

RESEARCH METHODS

This research an experimental study with the type of one-group pretest-posttest design. The sample of this research comprises a section of 24 first-year students of Informatics Engineering and Industrial Engineering majors. Demographic details of the research sample are depicted in Table 1.

Demographic Background	Research Sample	
	n	%
Gender		
Male	16	66.67%
Female	8	33.33%
Age		
17-19 years old	18	75%
20-22 years old	5	20.83%
> 22 years old	1	4.17%
Study of Program		
Informatics Engineering	13	54.17%
Industrial Engineering	11	45.83%

Table 1: Demographic Background of Research Sample (Engineering Students)

Table 1 shows that the demographic indicators of the research sample are used to refer to gender and the type of educational program taken by engineering students. The description of gender and type of educational program from research sample is needed to see a significant increase in student mathematics learning achievement per individual student level. The research data that measures engineering students of mathematics learning achievement used are the results of the calculus test on the sub-material of the application of definite integrals which are arranged in the form of a description test totaling 5 questions. The description test instrument is arranged based on the expected learning outcomes in these sub-materials. The assessment on the test instrument is arranged based on a rating scale that is adjusted to the stages of problem-solving per each test. The highest score for each question is 5 and the lowest score for each question is 1. If the student does not answer the test, then no score is given (no assessment is done). Meanwhile, the research data that measures students' learning motivation after using the flipped classroom model assisted by Autograph was compiled using Motivated Strategies for Learning Questionnaire (MSLQ) (Jackson, 2018; Pintrich et al., 1991) which has been modified according to the learning situation during the Covid-19 pandemic.

The two test instruments that had been developed are then tested for validation and reliability using Rasch Model Measurement analysis assisted by the Winstep application. The analysis was carried out using Winsteps using the Joint Maximum Likelihood Estimation (JMLE) equations that transform the raw data into interval data (logit) (Chang et al., 2020). The logit scale can indicate a person's skill and item's difficulty from positive infinity to negative infinity. The validation results show that the five description questions (the learning achievement instruments) and the learning motivation questionnaire developed are valid (according to the criteria for valid items regarding item response theory), namely the OUTFIT MNSQ value is in the range .5 to 1.5, the OUTFIT Z-STANDARD (ZSTD) value is in the range -2 to +2 and the Point Measurement Correlation (Pt. Measure Corr) value is in the range .4 to .85. The item's mean measure (logit) is .00, and the standard deviation (SD) is 34, indicating that item measurement variance in item difficulty was broad throughout the logit scale. For students, the mean measure was .66 logit, indicating that everyone was very enthusiastic about the study. Despite this, the person SD was .95, which is close to 1, demonstrating that person variation is suitable for data analysis. The five description test instruments were also declared reliable by referring to the results of the summary statistics test (Rasch Model Measurement) at the Reliability value (alpha = .68) in category enough for item and Reliability value (alpha = .76) in category good for a person (Sumintono & Widhiarso, 2015). Likewise, the learning motivation questionnaire was declared reliable by referring to the results of the summary statistics test (Rasch Model Measurement) at the Reliability value (alpha = .75) in category good. The summary statistics of item test and person can be seen in Table 2.

Statistic Test	Test Group	
	Person	Item Test
N	48	5
Measure	.66	0
Mean	17.2	165.2
SD	.95	.34
SE	.17	.20
Mean Outfit MNSQ	.99	.99
Mean Outfit ZSTD	.01	-.03
Separation	1.47	1.77
Reliability	.68	.76
Cronbach's Alpha	.69	

Table 2: The Summary of the Statistics Based on Pearson and Items

Questionnaire of student learning motivation in learning calculus using the flipped classroom model assisted by Autograph consists of 31 statements spread over three major domains, namely the value component, the expectation component, and the affective component. Each of these components is subdivided into six smaller domains which can be seen in Table 3.

Domain	Questionnaires Items
Value	
Intrinsic Goal Orientation	1, 16, 22, 24
Extrinsic Goal Orientation	7, 11, 13, 30
Task Value	4, 10, 17, 23, 26, 27
Expectancy	
Control of Learning Beliefs	2, 9, 18, 25
Self-Efficacy for Learning and Performance	5, 6, 12, 15, 20, 21, 29, 31
Affective	
Test Anxiety	3, 8, 14, 19, 28

Table 3: The Domain Rubric of Mathematics Learning Motivation Questionnaires

Questionnaires are given after the complete calculus learning using a flipped classroom model assisted by Autograph. The time needed to complete the questionnaire is less than 45 minutes. Students of Informatics Engineering and Industrial Engineering must read and answer the statements as prepared by the researchers. Next, they have to answer a questionnaire and choose a response option based on their learning experience.

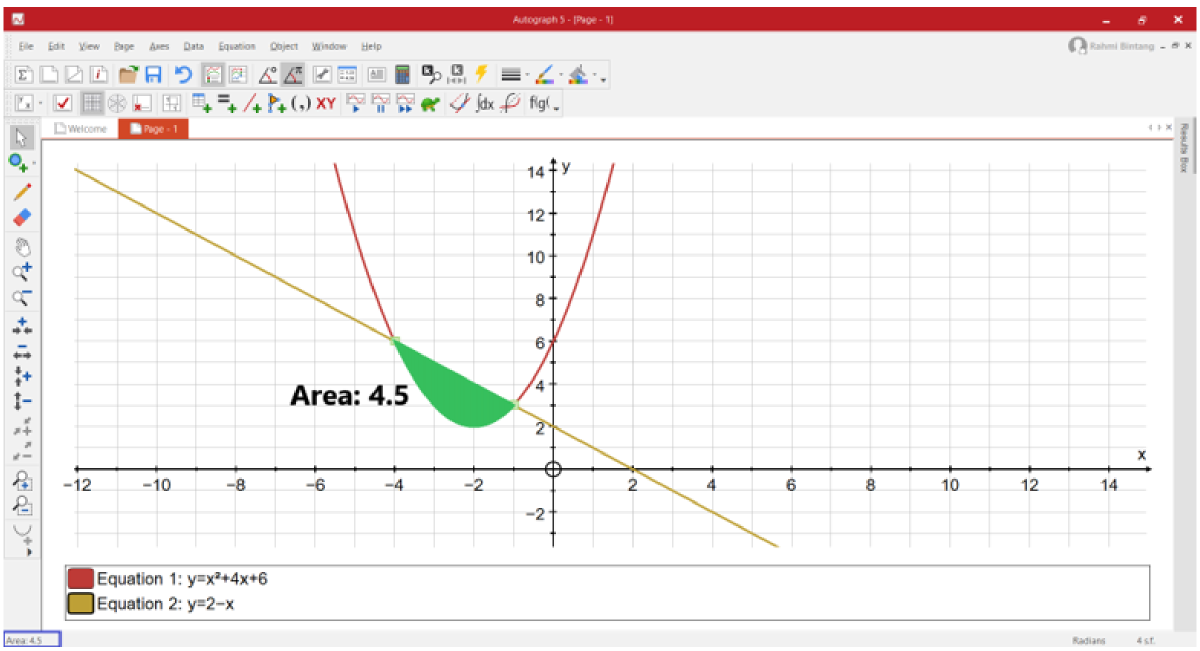
Next, the test instrument that has been valid and reliable is used as a test tool in the application of the flipped classroom model using Autograph in calculus learning. The data obtained are data before (N=24) and data after being given flipped classroom model learning using Autograph (N=24). The data used is not the final score obtained by each student, but the raw score on each description question that has been obtained by the student (both raw scores on the pretest and the posttest). The raw data is then analyzed using stacking analysis techniques. Analysis with data stacking techniques is used for intervention research designs that are pretest-posttest, where one group of respondents or subjects are tested at two different times (Arnold et al., 2018). The next data analysis will be seen based on two indicators, namely the mathematics learning achievement of each engineering student and the student's learning motivation after being taught using the flipped classroom model assisted by Autograph.

RESULTS AND DISCUSSION

The implementation of mathematics learning in many universities around the world during the Covid-19 pandemic was carried out using the flipped classroom model (Collado-Valero et al., 2021; Khan & Abdou, 2021; Tang et al., 2020). The flipped classroom model applied in this study uses lecture videos uploaded on a sharing site, to name YouTube, for the in-class phase and uses the LMS, to name Google Classroom, as a phase outside the classroom. Both phases of learning continue to use the Autograph application as a learning tool that aims to make it easier for engineering students to understand calculus. The students can make visualization on the abstract concepts of definite integral calculus in 2D and 3D design. They may calculate the area between the curves and the volume by typing the function in the Autograph's function box, then selecting the analysis option to calculate it. The interactive features of Autograph allow students to become engaged in explorations where the students themselves find the answers. One of the tests asked about finding the area between curves using Autograph can be seen in Figure 2.

Find the area between curves $y = x^2 + 4x + 6$ and $y = 2 - x$!

We can illustrate the graph from the function $y = x^2 + 4x + 6$ and $y = 2 - x$ in cartesian filed using Autograph.



Autograph can help us to find the area between curves (Area: 4.5)

Figure 2: The Test of Calculus Solving Using Autograph

Students can improve their mathematical abilities by using visualization in Autograph to calculate the area between curves, as shown in Figure 2. In addition, the students compare their Autograph solutions to manual computations. They can figure out how to calculate the area between curves without using a calculation. Before the learning is carried out, engineering students will be given a pretest consisting of calculus intending to see how far the engineering students understand the given calculus, especially definite integral. The same test will be given again after engineering students have finished learning using the flipped classroom model assisted by Autograph. The test results of both pretest and posttest were analyzed using the Stacking Analysis method on the Rasch Model Measurement with the help of the Winstep application. The results of the analysis will show the logit value obtained by each student based on the assessment per test item that has been given before and after learning. The logit value is the value of the logarithm function (logarithm odd unit). The use of logarithmic functions in measuring the improvement of students' mathematics learning achievement abilities is carried out on Rasch modeling which will be used as an analytical technique in this study. Rasch modeling not only measures the number of correct answers obtained by the students but also calculates the probability odds ratio for each item of the test instrument (Sumintono & Widhiarso, 2015). The use of stacking analysis in this study will provide information on how impactful the difference in the logit value is in the pretest and posttest conditions. The differences in mathematics learning achievement examined through the person logit data of each student in the pretest and posttest conditions can be seen in Figure 3.

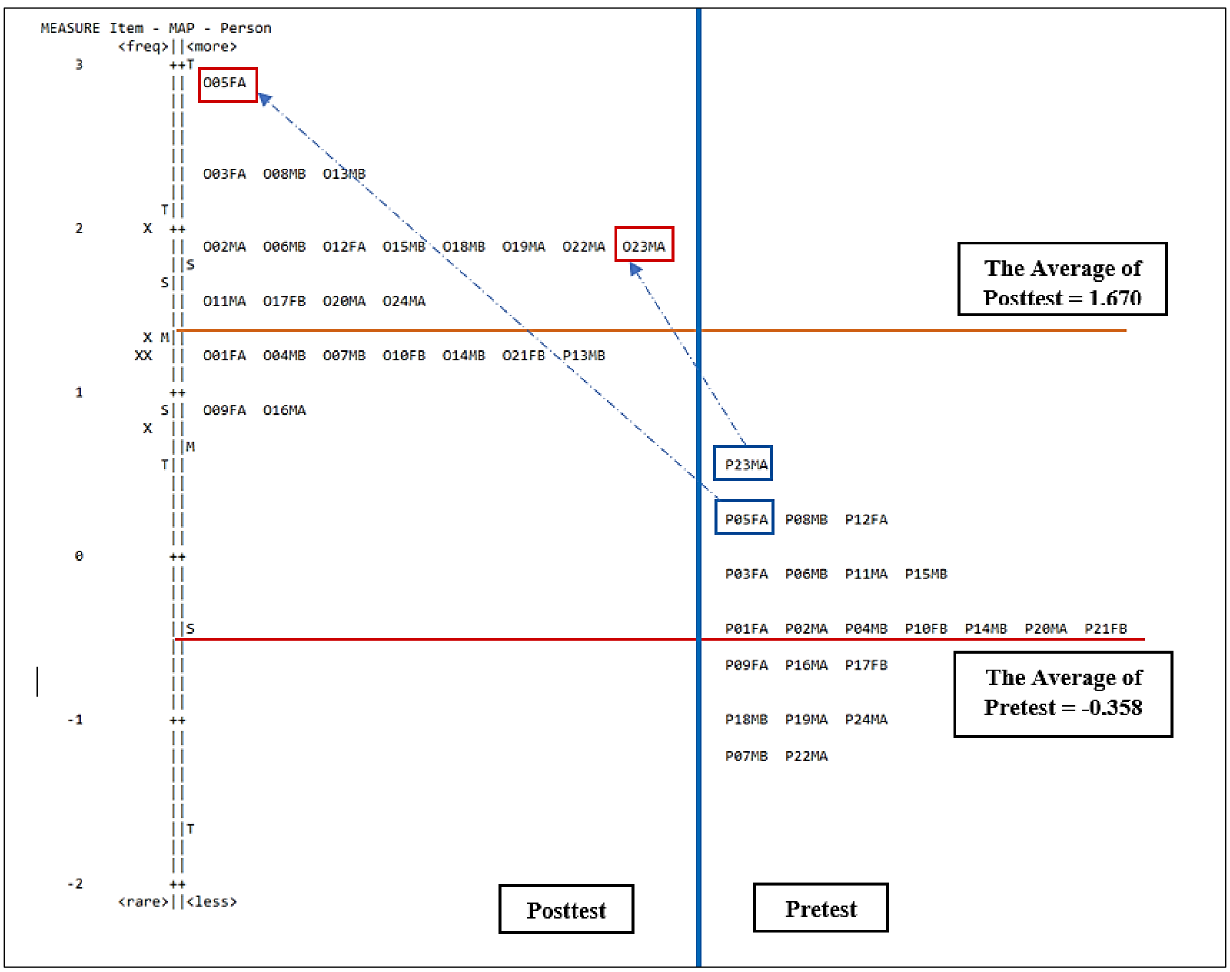
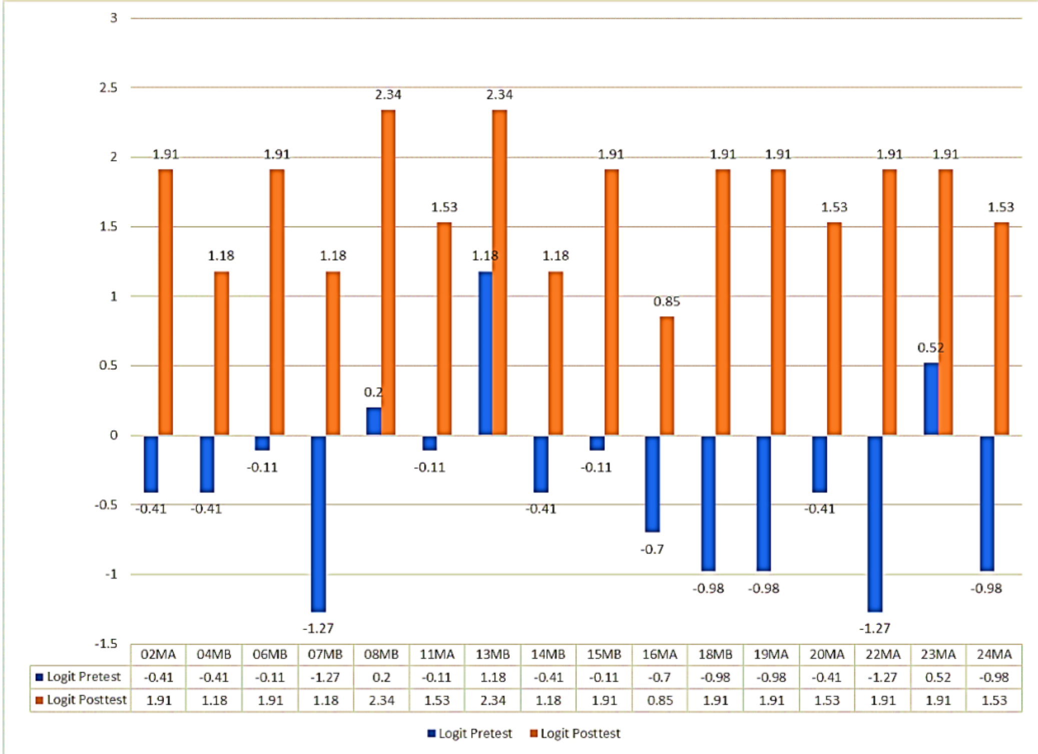


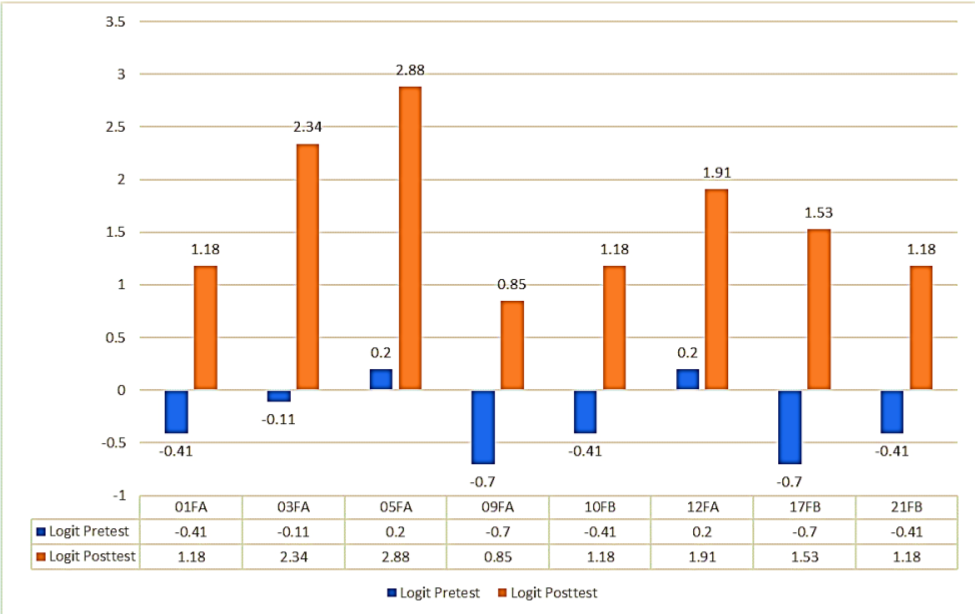
Figure 3: Pretest and Posttest Differences in Calculus Using Map Wright

Based on Figure 3, it can be seen that there are differences in the level of difficulty of each question given to engineering students. The question code is marked with the symbol X, and it can be seen that the level of difficulty of the questions given varies, there is 1 question in the category easy (Logit Value < +1), there are 3 questions in the category medium (+1 < Logit Value < +2), and 1 question in the category difficult (Logit Value > +2). It can also be seen in Figure 3 that there is an increase in the average logit value on the test results of engineering students before and after taking calculus using the flipped classroom model assisted by Autograph. The average logit value on the mathematics learning achievement of engineering students in the pretest obtained a value of -0.358 and experienced a significant increase in the posttest with an average logit value of 1.670. These results show that the level of understanding of engineering students in calculus is better after receiving instruction with a new model even though they are in the Covid-19 pandemic condition. Students with code P23MA had the highest logit value (+ .52) in the pretest, while students with code O05FA had the highest logit value (+2.88) in the posttest. In Figure 3, it can also be seen that the increase in the calculus achievement of one of the engineering students with the code 05FA experienced an increase in the logit value, from a logit value of less than +1 to a logit value greater than +2. The same changes were also experienced by almost all engineering students. This change in logit value also provides evidence that changes in the new learning environment and the use of appropriate supporting learning media can maximize student learning achievement (Cimermanová, 2018; Coman et al., 2020). More detail on how the graph of the increase per individual student based on the logit value obtained before and after taking calculus learning using the flipped classroom model assisted by Autograph can be seen in Figure 4, Figure 5, and Figure 6.



	02MA	04MB	06MB	07MB	08MB	11MA	13MB	14MB	15MB	16MA	18MA	19MA	20MA	22MA	23MA	24MA
Logit Pretest	-0.41	-0.41	-0.11	-1.27	0.2	-0.11	1.18	-0.41	-0.11	-0.7	-0.98	-0.98	-0.41	-1.27	0.52	-0.98
Logit Posttest	1.91	1.18	1.91	1.18	2.34	1.53	2.34	1.18	1.91	0.85	1.91	1.91	1.53	1.91	1.91	1.53

Figure 4: Graph of Logit Values-Based Changes in Mathematics Learning Achievement Before and After Treatment for Male Students



	01FA	03FA	05FA	09FA	10FB	12FA	17FB	21FB
Logit Pretest	-0.41	-0.11	0.2	-0.7	-0.41	0.2	-0.7	-0.41
Logit Posttest	1.18	2.34	2.88	0.85	1.18	1.91	1.53	1.18

Figure 5: Graph of Logit Values-Based Changes in Mathematics Learning Achievement Before and After Treatment for Female Students

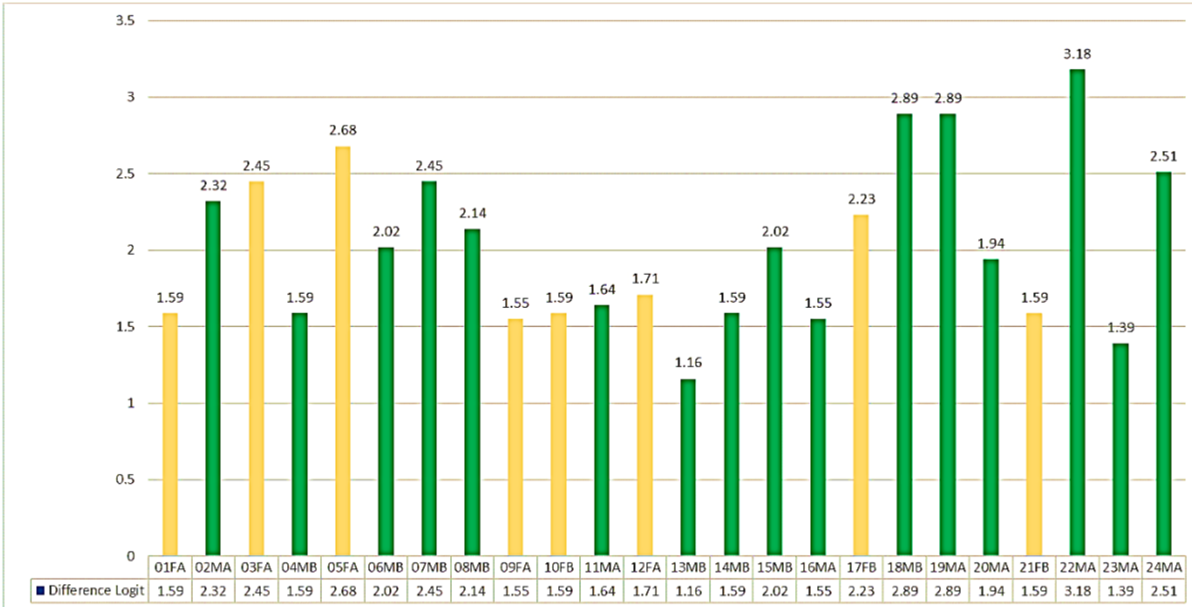


Figure 6: Graph of Difference Logit Values in Mathematics Learning Achievement

Based on Figure 6, it can be seen that the highest change in logit value is at +3.18 (code 22MA) and the lowest change in logit value is at +1.16 (code 13MB). In Figure 4 and 5, we can see that engineering students in the Informatics major (Code A) have a higher average change in calculus achievement than engineering students in the Industrial study program (Code B). The average change in the logit value for informatics engineering students shows a logit value of +2.108 while the industrial engineering student shows a logit value of +1.18. Based on the gender demographics, male students experienced a change in logit value (increased calculus learning achievement) both in informatics engineering students and industrial engineering students. The results of this analysis clearly show that both informatics engineering students and industrial engineering students simultaneously experience positive logit value changes which increase calculus learning achievement. The same thing applies to male students and female students as they experienced a significant increase in learning achievement. Although the change in the highest logit value was obtained by male students, female students obtained the highest logit value in both pretest and posttest. Indicators of differences in majors and genders on engineering students do not have a significant impact on changes in calculus learning achievement using the flipped classroom model assisted by Autograph. Changes in calculus learning achievement occurred due to the effects obtained from new learning treatments in the environment of engineering students during the Covid-19 pandemic. The flexibility, independence, and creativity created by the application of the flipped classroom model (Fernández-Martín et al., 2020; Quinn & Aarão, 2020) as well as the application of Autograph (Moksin et al., 2018; Zubainur et al., 2018) proved to have a real effect in improving students' mathematics learning outcomes.

The converging results are also obtained from the analysis of students' learning motivation after participating in learning using the flipped classroom model assisted by Autograph. Student responses regarding the motivation to learn calculus after participating in learning the flipped model with the help of Autograph can be seen in the Figure 7.

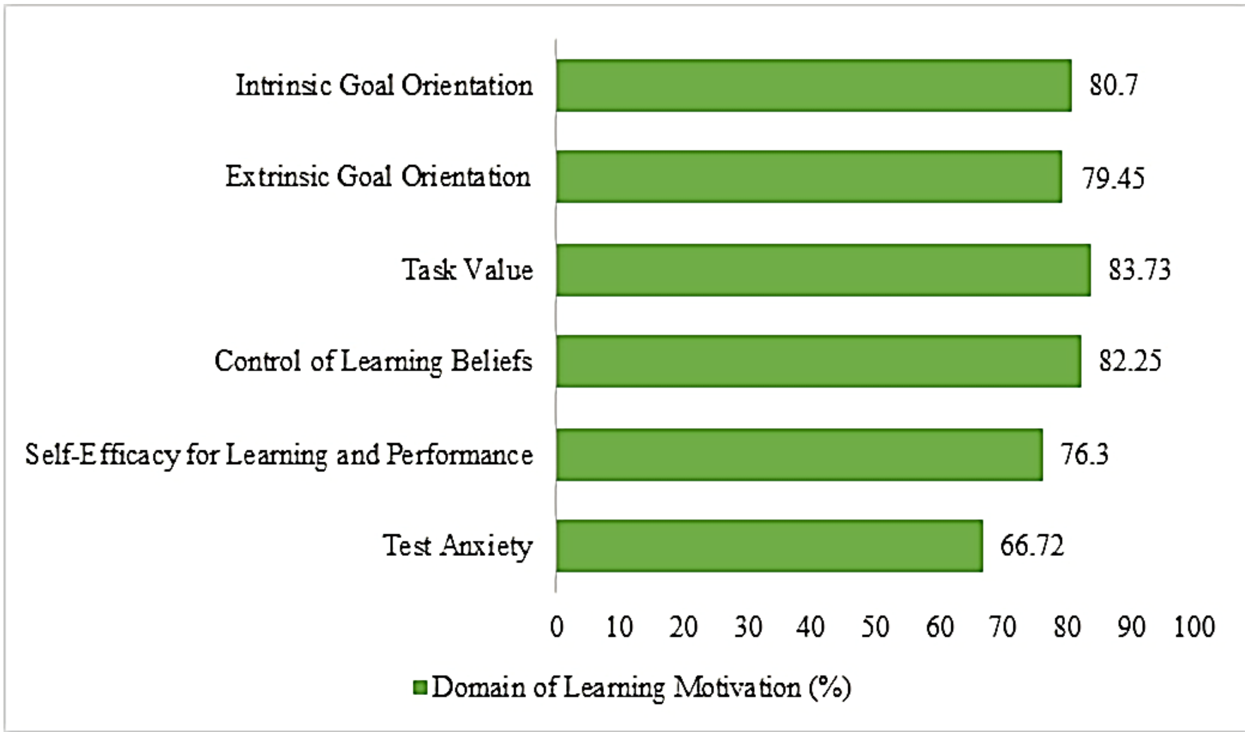


Figure 7: Graph of Student Learning Motivation Achievement

Figure 7 shows that the Task Value domain has a higher percentage value compared to other learning motivation domains, which is 83.73%. These results indicate that learning using the flipped classroom model assisted by Autograph gives special interest to engineering students and is very helpful for engineering students in completing the assignments given. The high task value also shows that students have progressed to develop their learning abilities (Colomo-Magaña et al., 2020). The results of the learning motivation questionnaire also show that the learning obtained by students provides a flexible learning atmosphere, increases collaboration between students and educators (McCarthy, 2016), can adapt to learning styles (Molnar, 2017; Mousa & Molnár, 2020), and the level of learning independence possessed by each student (Kim et al., 2017). The anxiety factor in dealing with the questions given as well as other external factors, such as personal, family, and self-control over the implementation of technology-based distance learning did not affect student learning achievement (Ramadhani et al., 2020; Tsai et al., 2017).

Based on the results of the questionnaire analysis of student learning motivation, students were very interested in participating in calculus learning using the flipped classroom model with the help of Autograph. Students are greatly helped in understanding calculus material, exceedingly definite integral calculus, and its application in learning conditions during the Covid-19 pandemic. Students also remain motivated to follow a series of learning stages that have been designed in this study. The results obtained when evaluated from the lecturer's perspective are not dissimilar to the analysis results on student learning motivation. During the Covid-19 epidemic, lecturers were excited about using the flipped classroom style to teach students. For lecturers who want to explore learning in the Covid-19 pandemic situation, the flipped classroom style is beneficial. Lecturers deliver information in the form of videos and maintain a collaborative and productive learning atmosphere which provides an organized discussion area with the help of the LMS. For lecturers, using Autograph as a learning medium in integral calculus gives a unique teaching experience. Lecturers can assist students in improving their mathematical reasoning skills by allowing them to find their answers using graphic visualization-assisted Autograph. Cevikbas & Kaiser (2020) strongly agreed that the use of LMS and mathematics-specific tools (mathematics video, dynamic software) are crucial if affordance enabling flipped classroom models are to be realized.

Flexibility, online courses, study management, technology, classroom learning, and online interaction were determined to be six markers of successful learning utilizing the flipped classroom approach by the mathematics instructors. Flipped classroom model accommodated those indicators, no wonder it makes learning successful. Flipped classroom model is one of the approaches suggested by various educationalists and research scholars throughout the globe, which will provide the learners with a powerful learning experience (Saboowala & Mishra, 2021). The researchers recommended that the flipped classroom model-assisted Autograph be implemented in other mathematics learning according to the research result.

CONCLUSIONS

Learning calculus using the flipped classroom model assisted by Autograph provides a new learning experience for engineering students. Graphic visualization presentations were designed by engineering students assisted with Autograph and collaborations through the flipped classroom model, proved to help students understand the concept of calculus integral. By that means, the teaching materials are designed in this study to be flexibly implemented in online learning, especially during the Covid-19 pandemic. Communication that exists between the engineering students and the educators can also be carried out well with the support of LMS-Google Classroom which is used in the classroom phase as a virtual class instead of a face-to-face class. The flipped classroom model's effectiveness is further aided by solid student-teacher interaction, autonomous learning, and the use of technology-integrated learning media Autograph, which keeps the virtual-based learning environment appealing and inspires students to participate in the learning process.

Other results are also shown by responses related to learning motivation questionnaires given to engineering students after the learning is done. Positive responses were given, and on the task value dimension, the students answered that the use of the flipped classroom model assisted by Autograph helped them develop their learning skills, thus gaining new knowledge. The results of this study are expected to be supporting data for educators in developing a flipped classroom model that is supported by other technology-integrated learning media. This research is also expected to be a benchmark for other researchers in conducting further experimental studies that focus on student learning activities after applying the flipped classroom model in learning mathematics.

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