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INTEGRATING STEAM INTO FLIP FLOP MODEL TO IMPROVE STUDENTS' UNDERSTANDING ON COMPOSITION OF FUNCTIONS DURING ONLINE LEARNING

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ABSTRACT

Some previous studies tried to improve students' understanding of the concept of the composition of functions. However, only some research results still examine efforts to increase student understanding of the concept taught online, especially by utilizing the STEAM-integrated Flip Flop learning model. Therefore, the purpose of this study is to analyze the level of effectiveness of the application of the STEAM-integrated Flip Flop model in increasing students' understanding of composition function material taught online. To answer the purpose of the study, the authors compared the model with the Flipped Learning model and the conventional learning model. The quantitative method with a pretest-posttest control group design model is employed in the present study by engaging 90 Indonesian senior high school students. This study finds that the STEAM-integrated Flip Flop model is significantly better at improving students' understanding of the composition of function concepts than conventional models. However, the same result is not found if compared with the Flipped Learning model. Though the average score of the STEAM-integrated Flip Flop model is better than the Flipped Learning model, the difference is not significant. This study also describes the related syntax of the STEAM-integrated Flip Flop model that high school math teachers can use to teach better composition functions online.

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1. INTRODUCTION

The composition functions is a fundamental concept in mathematics that involves combining two or more functions to create a new function; for instance, if given two functions, f, and g, their composition, denoted as $(f \circ g)(x)$, is defined as applying function g to the result of applying function f to the input x (Velleman, 2019). This concept can simplify complex functions by dividing them into smaller, more manageable parts (Trouillon et al., 2017). In mathematics, this concept can help practitioners in physics, engineering, economics, and computer science to model the phenomena they find so that they become more accurate and realistic by combining multiple functions that represent each phenomenon (Elber & Kim, 2014). Based on these benefits, the concept of composition functions becomes essential to learn, especially at the school level, as has been done in several countries such as Indonesia, China, and Singapore, which put the concept to be taught at the secondary school level. Some previous research has shown that this concept is quite challenging for students to learn and understand (Jojo et al., 2012; Modabbernia et al., 2023). Moreover, this situation becomes more complicated when this concept—as part of one branch of mathematics—is taught online, especially after the COVID 19 Pandemic, where online learning became the primary alternative to the face-to-face teaching-learning process (Khanal et al., 2022).

On the one hand, online learning makes mathematics learning flexible (Hendriana et al., 2019; Panjaitan et al., 2023). On the other hand, this learning model has limitations regarding location, space, and time, as not all students have equal access to any or all aspects of the online learning process (Aisyah & Murniati, 2022; Cooper, 2006). Moreover, according to the authors' experience in giving workshops for pre-service teachers during the last three years about online learning in Indonesia, many teachers still treat online learning the same as offline learning in such a way that the learning becomes uninteresting for students. Teachers tend only to give lectures, do not involve any multimedia learning, and do not use online learning strategies that can make it effective and efficient. This is in line with de Jong (2020), who claims that online teaching is an entirely different instructional concept that necessitates the development of skills that many educators lack and support that many institutions do not provide. These conditions can make it difficult for students to understand the mathematical concepts taught in the context of online learning mathematics. As a result, a learning model capable of making online learning effective and efficient is required, one of which is the Flip Flop model.

The Flip Flop model is a modified Flipped Learning model performed by Stelovska et al. (2016). The two models have the same syntax: pre-class, in-class, and post-class. According to Ogawa (2018), the condition of the learning video provided by the teacher at the pre-class activity stage distinguishes the two models. The video provided in the Flipped Learning model is only lecturing or explanation related to the material to be studied (Ishartono et al., 2022). In the Flip Flop model, there is a Flop element, which Stelovska et al. (2016) define as an additional element in the video where students can actively participate while watching the learning video provided by the teacher. These extra elements can take the form of investigative questions or quizzes embedded via a video timestamp. Although until now there have not been many research results that utilize this model, the results of research by Stelovska et al. (2016) show that the Flip Flop model can increase students' understanding of the material taught online. In addition, the results of research from Ogawa (2018) also showed an increase in learning performance from students after being actively involved in the learning process based on the Flip Flop model. But if pulled back to online mathematics learning, the Flip Flop model can be integrated with the STEAM approach which can make mathematics learning more comprehensive and interesting.

STEAM (Science, Technology, Engineering, Arts, and Mathematics) is an interdisciplinary educational approach that integrates these subjects to promote holistic and creative learning (Haesen & Van De Put, 2018). In mathematics learning, this approach can help teachers improve students' problem-solving skills, metacognition abilities, and computational thinking skills (Bedar & Al-Shboul, 2020; Diego-Mantecon et al., 2021; Pahmi et al., 2022; Wahba et al., 2022). More than that, applying the STEAM approach can improve the quality of learning and make it more meaningful for students by bridging disciplines to understand—one of them—mathematical concepts (Liliawati et al., 2018). Applying the STEAM approach to online learning can make material delivery more comprehensive (Kartika et al., 2021).

Based on previous research, few research results show efforts to improve students' understanding of the concept of composition of functions. Some of them are like research from Priyanto and Permatasari (2022) Try to improve students' understanding of the material using student worksheets based on problem-based learning models. Unfortunately, the research did not continue to the application stage, so the results were not comprehensive. Research results from Rezeki (2018), which utilizes Adobe Flash Cs6 integrated problem-based learning model to improve students' understanding of composition functions. However, no research has been conducted because of these two efforts to increase student understanding of the composition of functions during online learning, mainly when using the STEAM-integrated Flip Flop model. This is significant because, in addition to the concept of function composition having many benefits if understood by students, the findings of this study can be used as a guide for increasing student understanding of the concept during online learning. Therefore, the purpose of this study was to test the effectiveness of the STEAM-integrated Flip Flop model in increasing students' understanding of the concept of composition of function during online learning. In this study, the model will be compared with two other models, namely the Flipped Learning model and the conventional learning model where the teacher only teaches the concept of composition of function in lectures.

2. METHOD

2.1. Research design

The present study employs quantitative methods with a pretest-posttest-control-group design by comparing three sample groups that represent the three learning models: STEAM-integrated Flip Flop (Experiment 1), Flipped Learning (Experiment 2), and conventional learning (Control) (see Table 1).

Table 1. Research design

Sample Groups	Pre-test	Treatment	Post-test
Experiment 1	O_1	X_1	O_2
Experiment 2	O_3	X_2	O_4
Control	O_5	X_3	O_6

Table 1 shows the study design where O_1, O_3, and O_5 represent the pre-test for Experiment 1, Experiment 2, and Control group of samples, respectively. While O_2, O_4, and O_6 represent the post-test for the three groups. Regarding the treatment column, X_1 represents the treatment for Experiment 1, where the sample group is taught by using STEAM-based Flip Flop, X_2 represents the treatment for Experiment 2 where the sample group is taught by using Flipped Learning model, and X_3 represents the treatment for the Control where the sample group is taught by using the conventional model.

2.2. Participants

A total of 90 students from one of the senior high schools in Indonesia participated in the study, and they had previously voluntarily approved their participation. The students were from three classes which were randomly selected from six parallel classes available at the school. The background of these students is that they were in grade 11 during where the composition of functions material is taught in that grade. The selection of schools is based on the availability of facilities that support the implementation of online learning, such as internet availability and student readiness. The students were treated ethically according to the standard of the American Psychological Association (American Psychological Association, 1992).

2.3. Instrumentations and data analysis technique

To answer the objectives of the present study, researchers use data collection techniques in the form of cognitive tests with the concept of composition of function. The test consists of two question items where the questions were developed by considering Bloom's Taxonomy by Krathwohl and Anderson (2010). The two questions are description answer questions consisting of one question with cognitive level C3 (application), and one with cognitive level C4 (analysis). The scoring technique used is proportional based, where the total score of the two questions is 100, with the proportion of question number 1 (C3) is 30 and question number 2 (C4) is 70.

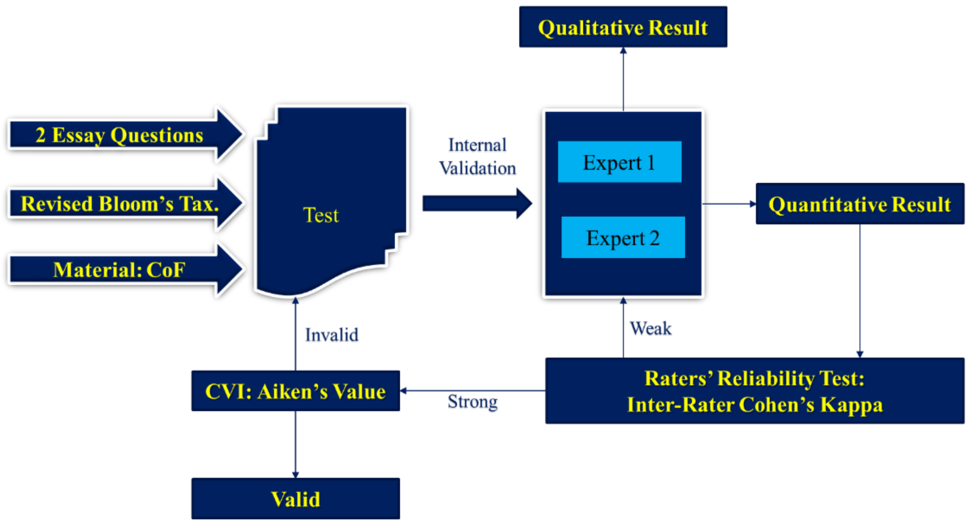


Figure 1. Instrument validation process

Next, the instrument was then tested for internal validity involving two experts from two private universities in Indonesia (see Figure 1 for the validity process). Both experts have mathematical education backgrounds and doctoral degrees and have experience in research in mathematics education. The instrument validity data is then used first to analyze the reliability level of the two experts using Cohen's Kappa Inter-Rater formula (Hsu & Field, 2003). Based on the analysis, the results obtained that the two experts have an agreement level of 0.831, so they are categorized as having a high level of reliability. Next, the internal validity results are then analyzed using Aiken's coefficient value formula to see the validity level of each question's content (Aiken, 1985). The analysis results showed that each question had a high level of validity, which was at 0.827. Then the instrument was piloted to 5 senior high school students—from outside the school used as a data collection site—to see if the questions were easy to understand and unambiguous for students. The results of the pilot test showed that there were some words that confused students enough to become revision material for the authors.

The instrument declared valid is then used to collect data on the pre-test and post-test. The data obtained were then conducted homogeneity and normality tests using SPSS 23. The data criteria are normally distributed and satisfy the homogeneity level if the significant value is over 0.05 (Zimmerman & Zumbo, 1992). The data can be analyzed parametrically using the single-track ANOVA test if declared normal and homogeneous.

2.4. Research procedures

The present study used three sample groups with three different treatments for each group: STEAM-integrated Flip Flop (SFF), Flipped Learning model (FL), dan conventional model (CM). The three sample groups are taught by the same teacher, that was the fifth author, and supervised by the first and the third author. In principle, SFF and FL have the same syntax, namely pre-class, in-class activity, and post-class activity, as conveyed by Bergmann and Sams (2012) (see Figure 2). What distinguishes the two models is the learning video used in the pre-class activity stage. In SFF, the learning videos used are integrated with timestamps and investigative questions. While in FL, the video used does not have any integration and only focuses on lecturing (see Figure 2).

The study was conducted from October to December 2022, and was commenced by making a coordination with the teachers in the three classes to discuss the implementation of each model in the three class and do pre-test for the students. Next, researchers carried out pre-class activities in the Experiment 1 and Experiment 2 classes. This stage begins with preparing a Learning Management System (LMS) for both classes where the LMS in class Experiment 1 is equipped with a STEAM-based composition of function learning video along with a list of investigative questions, while class Experiment 2 is given a video explaining the concept of composition of function. After everything was prepared, the researcher and the teacher asked students in Experiment 1 and Experiment 2 classes to study the video provided. Especially for the Experiment 1 class, researchers also ask students to answer questions contained in investigative questions.

In the in-class activity stage, researchers and teachers in Experiment 1 and Experiment 2 classes began the online learning by confirming their understanding related to the learning videos they had learned the previous day. Researchers and teachers confirm by giving 2 routine questions related to the concept of composition of function. After the students' basic understanding of the concept of composition of function was confirmed, researchers and teachers carry out core learning where for the Experiment 1 class, the core learning obtained is based on STEAM and HOTS (Higher Order Thinking Skills)-based activity. While in the Experiment 2 class, the core learning obtained is only based on HOTS. Finally, this stage is closed by drawing conclusions carried out by students and teachers and researchers. Lastly, in the post-class activity, students in the class of Experiment 1 and Experiment 2 were given posttest. Meanwhile, the control class only received pretest and posttest, without being given any treatment during online learning of composition of functions. The pre-test and post-test results of the three classes were then statistically analyzed.

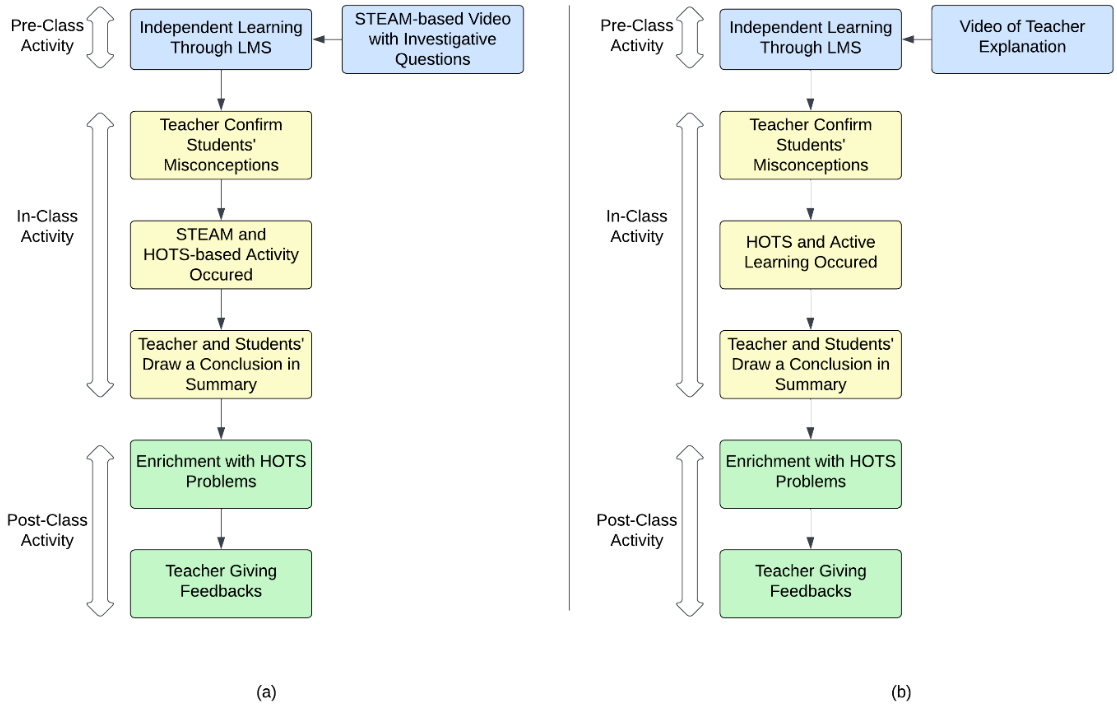


Figure 2. (a) syntax of SFF, (b) syntax of FL

2.5. Hypotheses

Some past studies have attempted to utilize the Flip Flop model to improve students' understanding online as done by Ogawa (2018) and Stelovska et al. (2016). Furthermore, some previous research has also utilized the STEAM model to improve students' understanding of mathematics learning (Ishartono et al., 2021; Martínez-Jiménez et al., 2022; Pahmi et al., 2022). Based on some of these previous studies, the author hypothesizes that integrating the Flip Flop and STEAM approach can improve students' understanding of the concept of composition functions. The hypothesis can be formulated as follows:

H_1 : There are significant differences among the three sample groups.

H_2 : The sample group of Experiment 1 had a higher average score compared to the sample group of Experiment 2.

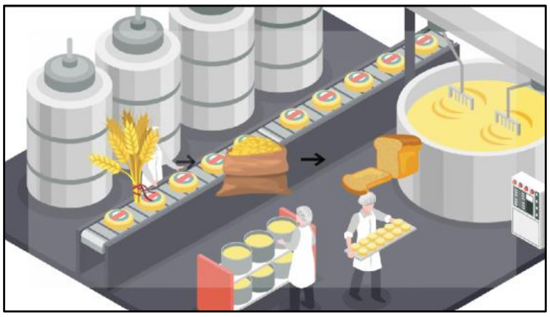
H_3 : The sample group of Experiment 1 had a higher average score compared to the sample group of Control.

3. RESULT AND DISCUSSION

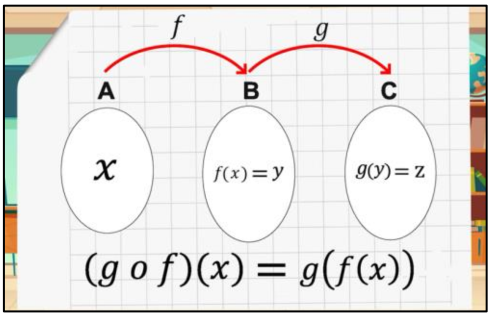
3.1. Results

3.1.1. STEAM-based learning media and investigative questions

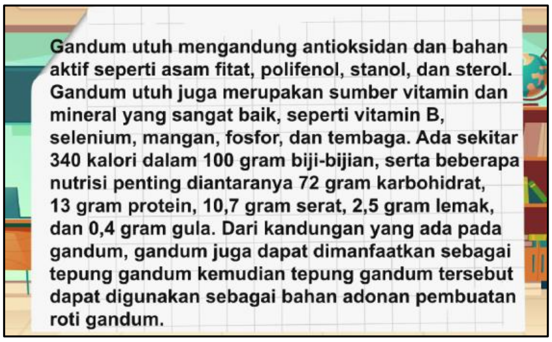
The most distinguishing thing in the Flip Flop design in this study and in the Flipped Learning design is the characteristics of learning media used in the pre-class activity phase. In this study, the learning media used was learning videos integrated with the STEAM approach (please access https://youtu.be/XGnDpRKQX9I). The video uses the context of three of STEAM's five elements: science, technology, and mathematics, which is summarized in the context of producing a loaf of bread in a bakery. In the video, the bread production process is visualized from starting in the form of wheat grains into wheat flour and reprocessed into bread. Then from the production process, the author models it into the mathematical representation of the composition of functions (see Figures 3.a and 3.b). In addition, the learning video also explained the chemical content contained in wheat. This explanation can strengthen students' understanding of the composition of functions associated with aspects of science (see Figure 3.c). The video can be accessed through the YouTube platform, which allows timestamp facilities, as Stelovska et al. (2016) recommended. In addition to making, it easier for students to choose explanatory topics in learning videos, using timestamps that investigative questions act as reinforcement of students' understanding of the concept of composition of function taught in the learning video. Some examples of investigative questions are something like "At 1:49 a.m., what happens if the equation of the composition function $(g \ o \ f)\ (x) = g(f(x))$ is changed to $(f \ o \ g)(x) = f(g(x))$? Are the two functions of the composition the same?".



(a)



(b)



(c)

Translation for (c):
Whole grains contain antioxidants and active ingredients such as phytic acid, polyphenols, stanols, and sterols. Whole grains are also an excellent source of vitamins and minerals, such as B vitamins, selenium, manganese, phosphorus, and copper. There are about 340 calories in a 100-gram grain, as well as some important nutrients including 72 grams of carbohydrates, 13 grams of protein, 10.7 grams of fiber, 2.5 grams of fat, and 0.5 grams of sugar. From the content of wheat flour can then be used as a dough ingredient for making wheat bread.

Figure 3. Some prominent parts of the STEAM-based learning video

3.1.2. Pre-test data analysis results

Before starting the study, the author gave a pre-test to the research subjects; the pre-test test results will determine whether the three samples selected are suitable for use as sample groups in this study. The feasibility is based on whether the three sample groups have balanced abilities related to critical thinking skills. Therefore, it is necessary to conduct a balance test using a parametric statistical test, namely One-Way ANOVA. However, to be able to carry out the test, a statistical prerequisite test was first carried out to see whether the abilities of students from the three sample groups were normally distributed and had homogeneous variants. The normality test uses the Shapiro-Wilk formula (see Table 2), while the homogeneity test uses the Levene test (see Table 3) (Zimmerman & Zumbo, 1992).

Table 2 shows the significant values of the sample group Experiment 1 at level of 0.066, Experiment 2 at level 0.082, and Control at level 0.071. This shows that all three sample groups have normally distributed data. Furthermore, Table 3 shows the level of homogeneity of the three sample groups, which shows a significant value at the level of 0.793 which means that the data from the three sample groups are homogenous. Because the pre-test data is normally distributed and homogenous, the data can be tested further using One-Way ANOVA to see the significance of the average difference between the three sample groups.

Table 4 shows the result of the One-Way ANOVA test for the pre-test data showing a significance value at 0.882. In other words, the number shows that there is no significant difference from the average pre-test data of each sample group. This is reinforced by the average value shown in Table 5 related to the descriptive statistical analysis results on pre-test data. Thus, the results of the analysis of the One-Way ANOVA test can be interpreted as the students' ability in the three sample groups is relatively the same, so the group sample can be used for the research.

Table 2. Result of shapiro-wilk normality test for pre-test data

Sample Group	Statistic	df	Sig.	Criteria
Experiment 1	0.935	30	0.066	Normal
Experiment 2	0.938	30	0.082	Normal
Control	0.936	30	0.071	Normal

Table 3. Levene homogeneity test result for pre-test data

Sample Group	N	Levene Statistics	df1	df2	Sig.	Criteria
Experiment 1	30					
Experiment 2	30	0.232	2	87	0.793	Homogenous
Control	30					

Table 4. One-way ANOVA test for pre-test data

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	52.422	2	26.211	0.125	0.882
Within Groups	18195.233	87	209.141		
Total	18247.656	89			

Table 5. Descriptive statistical analysis for pre-test data

Sample Group	N	Mean	Std. Deviation
Experiment 1	30	23.7000	14.72308
Experiment 2	30	21.8667	14.10242
Control	30	22.4667	14.55248

3.1.3. Post-test data analysis results

After the three sample groups were given treatment as stated in the research design (see Table 1), the author gave a post-test to students regarding their understanding of the concept of composition of functions. This post-test aims to measure how effectively the application of the SFF model increases students' understanding of the composition of functions compared to the FL or CM model. Therefore, the post-test results were analyzed with inferential parametric statistical tests using the One-Way ANOVA test to see if there was a significant difference in mean values between the sample groups. If there is, then the statistical test is followed by a post hoc test using the Scheffe formula (Brown, 2005). Therefore, post-test data are first carried out a normality test and homogeneity test to determine whether the post-test data passes the parametric statistical prerequisite test.

Table 6 shows the normality test results on the post-test data. From the table, the significance value is obtained in the sample group Experiment 1 is 0.058, Experiment 2 is 0.174, and Control is 0.152. From these values, it can be said that all post-test data in the sample group are normally distributed. Next, Table 7 shows the level of homogeneity of the post-test data of the three sample groups. The table shows a significant value at the level of 0.203, meaning the data is homogeneous.

After confirming that the post-test data is normally distributed and homogeneous, a One-Way ANOVA test is carried out to determine whether there is a significant difference from the average of the three sample groups. Table 8 shows the results of the One-Way ANOVA test analysis, where the significant value is at the level of 0.037, which means that there is a significant difference between the three sample groups. Thus, to find out how effective the SFF model is compared to the FL or CM model, a post hoc test analysis with the Scheffe formula is carried out. Table 10 shows the results of post hoc analysis on post-test data which shows that the application of the SFF model has a significant impact in increasing students' understanding of the concept of composition of functions compared to the application of the CM model with a significant value of 0.049. Meanwhile, when compared with the results of the application of the FL model, the significance value obtained is 0.166, which means that the average difference between the application of the SFF and FL models is not significant. However, it can be seen in Table 9 that the average value of applying the SFF model is higher than the average value of applying the FL model.

Table 6. Result of shapiro-wilk normality test for posttest data

Sample Group	Statistic	df	Sig.	Criteria
Experiment 1	0.933	30	0.058	Normal
Experiment 2	0.950	30	0.174	Normal
Control	0.948	30	0.152	Normal

Table 7. Levene homogeneity test result for posttest data

Sample Group	N	Levene Statistics	df1	df2	Sig.	Criteria
Experiment 1	30					
Experiment 2	30	1.624	2	87	0.203	Homogenous
Control	30					

Table 8. One-way ANOVA test for post-test data

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1319.622	2	659.811	3.420	0.037
Within Groups	16784.600	87	192.926		
Total	18104.222	89			

Table 9. Descriptive statistical analysis for post-test data

Sample Group	N	Mean	Std. Deviation
Experiment 1	30	83.8333	11.91662
Experiment 2	30	76.9667	14.31296
Control	30	74.8667	15.22868

Table 10. Post hoc test for post-test data

Sample Group		Mean Dif.	Sig.	Description
Experiment 1	Experiment 2	6.86667	0.166	Not Significant
	Control	8.96667	0.049	Significant
Experiment 2	Experiment 1	-6.86667	0.166	Not Significant
	Control	2.10000	0.843	Not Significant
Control	Experiment 1	-8.96667	0.049	Significant
	Experiment 2	-2.10000	0.843	Not Significant

3.2. Discussion

The purpose of this study was to test how effective the STEAM-integrated Flip Flop (SFF) model is compared to the application of the Flipped Learning (FL) model and conventional (CM) model in increasing students' understanding of the concept of composition of function during online mathematics learning. To answer the purpose of the study, the present study uses three hypotheses that will be answered in this section.

The first hypothesis (H1) is about whether there is a significant difference in the average value of student understanding of the composition of function material taught online based on the application of SFF, FL, and CM models. Based on the results obtained (see Table 8), it can be concluded that H1 is accepted. This means that the application of the three models has a different impact on each other's understanding of the composition of function taught online.

The second hypothesis (H2) is related to whether the sample group of Experiment 1 has a significant average difference compared to the sample group of Experiment 2. Based on Table 9, the average sample group Experiment 1 is higher (83.8333) than the sample group Experiment 2 (76.9667). However, the post hoc analysis (see Table 10) showed that although students' average scores based on applying the two models differed, the significance level was at .166. This means that the difference is insignificant, or in other words, if the application of SFF compared to FL in a sample group located at another locus may be that the application of the FL model can give a higher average value than the application of the SFF model.

The last hypothesis (H3) is whether the sample group Experiment 1 significantly differs in mean values from the sample group control. Table 9 shows that the mean value of the sample group of Experiment 1 is higher than the average value of the sample group control (74.8667). On the other hand, the post hoc test results shown in Table 10 show a significant value at the level of .049, which means that the average difference between the two sample groups is significant. Thus, applying the SFF model can significantly increase students' understanding of the composition of function material taught online compared to applying conventional models.

Based on the analysis of the three hypotheses, the findings of this study are that the application of the SFF model has a significantly better impact than the application of the CM model in increasing students' understanding of the concept of composition of function taught online. Undeniably, the STEAM approach's role has become significant in syntax. Several previous studies have shown that STEAM can help students improve student understanding of the material taught online (Sigit et al., 2022; Zb et al., 2021). In addition, the role of learning videos as a multimedia learning medium can help students visualize mathematical work objects on the concept of abstract composition functions (Lalian, 2018). However, the application of the SFF model does not provide a significant difference in the average value of the application of the FL model, even though quantitatively, the average value of the application of the SFF model is better than the average value of the application of the FL model. This finding aligns with a previous study conducted by Ishartono et al. (2022) which shows that modified Flipped Learning models can effectively improve the quality of online mathematics learning compared to conventional models. This finding also aligns with the research conducted by Hwang and Lai (2017), which shows that modified flipped learning improves the quality of online mathematics learning than conventional flipped learning models.

Empirically, the integration of STEAM in the online learning process has been done quite a lot by several previous researchers. Although not specifically related to the Flip Flop model, some previous studies have linked it to the Flipped Classroom model (Han et al., 2020; Karampa & Paraskeva, 2018; Sutama et al., 2020). What distinguished between Flip Flop and Flipped Classroom is in the context of the learning video used in the pre-class activity stage. In Flipped Classroom, the video used is the result of learning recordings that occur in class, so students are asked to follow the results of the learning recordings. While in Flip Flop, the video is a tutorial and has a Flop aspect, namely a timestamp that helps students to be more engaged with the learning video they learn (Latorre-Cosculluela et al., 2021; Ogawa, 2018). In online mathematics learning, the Flipped Classroom model is seen as not helping students significantly because students are not actively involved in knowledge construction, and only watch recorded learning videos. On the other hand, the Flip Flop model provides ample space for teachers to be creative in embedding additional applications in learning videos that are oriented towards active student engagement while studying the learning videos provided.

The results of this research can be utilized by policy makers in the institutions or countries they manage to be able to improve the quality of learning on composition of functions material, or more generally on mathematics learning, online to be more effective and efficient. In addition, the results of this research can also be an alternative solution for practitioners in the world of mathematics education in carrying out online mathematics learning more effectively and efficiently. Of course, its use is not only bound to the composition of function material, but also to other materials. However, beyond the significance of the present research findings, some aspects of the present study can be elaborated more. Some of them are related to the material taught where in subsequent research can use other material contexts, such as geometry or arithmetic. Next is the STEAM context, where mathematics and technology are used in this study. Therefore, future studies can explore other components in the STEAM realm as the basis of learning videos at the pre-class activity stage and learning activities at the in-class activity stage. The last is in the context of research subjects, where in the present study, the number of research subjects was 90 students from only one school. Therefore, future studies can engage more students to participate in the study.

4. CONCLUSION

The present study aims to analyze the effectiveness of the STEAM-integrated Flip Flop model in increasing students' understanding of composition function material taught online. Based on the results of One-Way ANOVA analysis and post hoc tests, it was found that the application of the STEAM-integrated Flip Flop model was more able to increase students' understanding of the concept of composition functions significantly compared to the application of the conventional model, but not significantly to the application of the Flipped Learning model even though the average value resulting from the application of the STEAM-integrated Flip Flop model was better than the application of the Flipped Learning model.

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REFERENCES

Aiken, L. R. (1985). Three coefficients for analyzing the reliability and validity of ratings. *Educational and Psychological Measurement*, *45*(1), 131-142. https://doi.org/10.1177/0013164485451012

Aisyah, T., & Murniati, M. (2022). Online learning in the time and post COVID-19 pandemic. In *(pp. 148-155)*. https://doi.org/10.2991/assehr.k.220302.023

American Psychological Association. (1992). Ethical principles of psychologists and code of conduct. *American psychologist*, *47*(12), 1597-1611.

Bedar, R. A.-H., & Al-Shboul, M. A. (2020). The effect of using STEAM approach on developing computational thinking skills among high school students in Jordan. *International Journal of Interactive Mobile Technologies (iJIM)*, *14*(14), 80-94. https://doi.org/10.3991/ijim.v14i14.14719

Bergmann, J., & Sams, A. (2012). *Flip your classroom: Reach every student in every class every day*. International society for technology in education.

Brown, A. M. (2005). A new software for carrying out one-way ANOVA post hoc tests. *Computer Methods and Programs in Biomedicine*, *79*(1), 89-95. https://doi.org/10.1016/j.cmpb.2005.02.007

Cooper, M. (2006). Making online learning accessible to disabled students: an institutional case study. *Research in Learning Technology*, *14*(1), 103-115. https://doi.org/10.3402/rlt.v14i1.10936

de Jong, P. G. M. (2020). Impact of moving to online learning on the way educators teach. *Medical Science Educator*, *30*(3), 1003-1004. https://doi.org/10.1007/s40670-020-01027-7

Diego-Mantecon, J.-M., Prodromou, T., Lavicza, Z., Blanco, T. F., & Ortiz-Laso, Z. (2021). An attempt to evaluate STEAM project-based instruction from a school mathematics perspective. *ZDM – Mathematics Education*, *53*(5), 1137-1148. https://doi.org/10.1007/s11858-021-01303-9

Elber, G., & Kim, M.-S. (2014). Modeling by composition. *Computer-Aided Design*, *46*, 200-204. https://doi.org/10.1016/j.cad.2013.08.032

Haesen, S., & Van De Put, E. (2018). *STEAM education in Europe: A comparative analysis report*. Eurosteam project.

Han, W., Qi, T., Yang, J., Zhao, F., & Jin, X. (2020). Research on blended learning mode based on network. In 2020 2nd International Workshop on Artificial Intelligence and Education *(pp. 39-43)*. https://doi.org/10.1145/3447490.3447498

Hendriana, H., Putra, H. D., & Hidayat, W. (2019). How to design teaching materials to improve the ability of mathematical reflective thinking of senior high school students in Indonesia? *Eurasia Journal of Mathematics, Science and Technology Education*, *15*(12), em1790. https://doi.org/10.29333/ejmste/112033

Hsu, L. M., & Field, R. (2003). Interrater agreement measures: Comments on Kappan, Cohen's Kappa, Scott's π, and Aickin's α. *Understanding Statistics*, *2*(3), 205-219. https://doi.org/10.1207/S15328031US0203_03

Hwang, G.-J., & Lai, C.-L. (2017). Facilitating and bridging out-of-class and in-class learning: An interactive e-book-based flipped learning approach for math courses. *Journal of Educational Technology & Society*, *20*(1), 184-197.

Ishartono, N., Nurcahyo, A., Waluyo, M., Razak, R. A., Sufahani, S. F., & Hanifah, M. (2022). GeoGebra-based flipped learning model: An alternative panacea to improve students' learning independency in online mathematics learning. *Journal of Research and Advances in Mathematics Education*, *7*(3), 178-195. https://doi.org/10.23917/jramathedu.v7i3.18141

Ishartono, N., Sutama, Prayitno, H. J., Irfan, M., Waluyo, M., & Sufahani, S. F. B. (2021). An investigation of Indonesian in-service mathematics teachers' perception and attitude toward STEAM education. *Journal of Physics: Conference Series*, *1776*(1), 012021. https://doi.org/10.1088/1742-6596/1776/1/012021

Jojo, Z. M. M., Maharaj, A., & Brijlall, D. (2012). Reflective abstraction and mathematics education: The genetic decomposition of the chain rule--work in progress. *US-China Education Review*, *B*(4), 408-414.

Karampa, V., & Paraskeva, F. (2018). A motivational design of a flipped classroom on collaborative programming and STEAM. In L. Uden, D. Liberona, & J. Ristvej, In *Learning Technology for Education Challenges*, *(pp. 226-238)*. Cham https://doi.org/10.1007/978-3-319-95522-3_19

Kartika, E. F. R., VH, E. S., & Indriyanti, N. Y. (2021). Development and validation of web-based STEAM online platform to improve learning quality in pre-service Chemistry teacher. *JOTSE*, *11*(2), 513-525. https://doi.org/10.3926/jotse.1316

Khanal, B., Joshi, D. R., Adhikari, K. P., Khadka, J., & Bishowkarma, A. (2022). Factors associated with the problems in teaching mathematics through online mode: A context of Nepal. *International Journal of Education and Practice*, *10*(3), 237-254. https://doi.org/10.18488/61.v10i3.3097

Krathwohl, D. R., & Anderson, L. W. (2010). Merlin C. Wittrock and the Revision of Bloom's Taxonomy. *Educational Psychologist*, *45*(1), 64-65. https://doi.org/10.1080/00461520903433562

Lalian, O. N. (2018). The effects of using video media in mathematics learning on students' cognitive and affective aspects. *AIP Conference Proceedings*, *2019*(1), 030011. https://doi.org/10.1063/1.5061864

Latorre-Cosculluela, C., Suárez, C., Quiroga, S., Sobradiel-Sierra, N., Lozano-Blasco, R., & Rodríguez-Martínez, A. (2021). Flipped classroom model before and during COVID-19: using technology to develop 21st century skills. *Interactive Technology and Smart Education*, *18*(2), 189-204. https://doi.org/10.1108/ITSE-08-2020-0137

Liliawati, W., Rusnayati, H., Purwanto, P., & Aristantia, G. (2018). Implementation of STEAM education to improve mastery concept. *IOP Conference Series: Materials Science and Engineering*, *288*(1), 012148. https://doi.org/10.1088/1757-899X/288/1/012148

Martínez-Jiménez, E., Nolla de Celis, Á., & Fernández-Ahumada, E. (2022). The city as a tool for STEAM education: Problem-posing in the context of math trails. *Mathematics*, *10*(16), 2995. https://doi.org/10.3390/math10162995

Modabbernia, N., Yan, X., & Zazkis, R. (2023). When algebra is not enough: a dialogue on the composition of even and odd functions. *Educational Studies in Mathematics*, *112*(3), 397-414. https://doi.org/10.1007/s10649-022-10189-7

Ogawa, M.-B. (2018). Evaluation of Flip-Flop Learning Methodology. In P. Zaphiris & A. Ioannou, In *Learning and Collaboration Technologies. Learning and Teaching, (pp. 350-360)*. Cham https://doi.org/10.1007/978-3-319-91152-6_27

Pahmi, S., Juandi, D., & Sugiarni, R. (2022). The effect of STEAM in mathematics learning on 21st century skills: A systematic literature reviews. *Prisma*, *11*(1), 93-104. https://doi.org/10.35194/jp.v11i1.2039

Panjaitan, S. M., Hutauruk, A. J. B., Sitepu, C., Gultom, S. P., Sitorus, P., Marbun, M. R., & Sinaga, C. H. (2023). Implementation of online learning and its impact on learning achievements of mathematics education students. *Infinity Journal*, *12*(1), 41-54. https://doi.org/10.22460/infinity.v12i1.p41-54

Priyanto, M., & Permatasari, D. (2022). Students' worksheets based on problem based learning in composition and inverse functions to enhance conceptual understanding. *JRPM (Jurnal Review Pembelajaran Matematika)*, *7*(1), 73-88. https://doi.org/10.15642/jrpm.2022.7.1.73-88

Rezeki, S. (2018). Pemanfaatan adobe flash cs6 berbasis problem based learning pada materi fungsi komposisi dan fungsi invers [Utilization of Adobe Flash CS6 based on problem-based learning in material on composition functions and inverse functions]. *Jurnal Pendidikan Tambusai*, *2*(2), 856-864.

Sigit, D. V., Ristanto, R. H., & Mufida, S. N. (2022). Integration of project-based e-learning with STEAM: An innovative solution to learn ecological concept. *International Journal of Instruction*, *15*(3), 23-40. https://doi.org/10.29333/iji.2022.1532a

Stelovska, U., Stelovsky, J., & Wu, J. (2016). Constructive learning using flip-flop methodology: Learning by making quizzes synchronized with video recording of lectures. In P. Zaphiris & A. Ioannou, In *Learning and Collaboration Technologies, (pp. 70-81)*. Cham https://doi.org/10.1007/978-3-319-39483-1_7

Sutama, S., Prayitno, H. J., Ishartono, N., & Sari, D. P. (2020). Development of mathematics learning process by using flipped classroom integrated by STEAM Education in senior high school. *Universal Journal of Educational Research*, *8*(8), 3690-3697. https://doi.org/10.13189/ujer.2020.080848

Trouillon, T., Dance, C. R., Welbl, J., Riedel, S., Gaussier, É., & Bouchard, G. (2017). Knowledge graph completion via complex tensor factorization. *Journal of Machine Learning Research*, *18*, 1-38.

Velleman, D. J. (2019). *How to prove it: A structured approach*. Cambridge University Press.

Wahba, F. A.-A., Tabieh, A. A. S., & Banat, S. Y. (2022). The power of STEAM activities in enhancing the level of metacognitive awareness of mathematics among students at the primary stage. *Eurasia Journal of Mathematics, Science and Technology Education*, *18*(11), em2185. https://doi.org/10.29333/ejmste/12562

Zb, A., Novalian, D., Ananda, R., Habibi, M., & Sulman, F. (2021). Distance learning with STEAM approaches: Is the effect on the cognitive domain? *Jurnal Educative: Journal of Educational Studies*, *6*(2), 128-139. https://doi.org/10.30983/educative.v6i2.4977

Zimmerman, D. W., & Zumbo, B. D. (1992). Parametric alternatives to the Student T Test under violation of normality and homogeneity of variance. *Perceptual and Motor Skills*, *74*(3), 835-844. https://doi.org/10.2466/pms.1992.74.3.835