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Integrating GeoGebra into the flipped learning approach to improve students' self-regulated learning during the covid-19 pandemic

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Abstract

The Covid-19 pandemic has forced an immediate transition from face-to-face learning in classrooms to online learning, including math learning. Mathematics with abstract working objects is not easy to learn online. So, an excellent self-regulated learning ability is required. So far, many efforts have been made to improve self-regulated learning in mathematics learning. However, there are still gaps in improving students' self-regulated learning ability in online mathematics learning, especially in relation to the integration of GeoGebra into the Flipped Learning approach. The purpose of this study is to examine the effectiveness of integrating GeoGebra into the Flipped Learning approach to improve students' self-regulated learning ability in learning mathematics online during the Covid-19 pandemic. This research is a quasi-experimental study with a pretest-posttest control group design to compare the effectiveness of a GeoGebra-integrated Flipped Learning approach. A conventional Flipped Learning approach and a conventional learning approach increase students' self-regulated learning level in constructing their understanding of mathematical concepts during online learning in the Covid-19 pandemic. The study involved 60 students randomly selected from one of Indonesia's private universities. They were divided into three groups representing each approach. Pretest and posttest results were quantitatively analyzed using Normalized Gain (N-Gain) Score, Cohen's d effect size, and statistical descriptive. The analysis results revealed that GeoGebra-integrated Flipped Learning is more effective in increasing students' self-regulated learning level in online mathematics learning than the other two approaches. It is expected that the results of this study can provide insights into alternative solutions for improving the quality of online mathematics learning by increasing the level of self-regulated learning of students.

Keywords: Aiken's Coefficient Value, Covid-19, Flipped Learning, GeoGebra, Self-Regulated Learning

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On June 30, 2020, the World Health Organization (WHO) reported more than ten million cases of people exposed to coronavirus (Covid-19), of which 503,862 people died. This record eventually forced the WHO to announce that the emergence of Covid-19 was already at the pandemic stage, and all countries were required to take the condition seriously (World Health Organization, 2020). One of the steps taken by all countries to reduce the spread of Covid-19 is issuing policies that can minimize interaction and physical contact between people, called *social distancing*. As one of the countries affected by the spread of Covid-

19, Indonesia issued the lockdown and social distancing policies (Kemensesneg RI, 2020).

The policies issued by the Indonesian government have a massive and systemic impact on all sectors, including the education sector. The education sector is one of the sectors in which many parties are involved in the implementation, such as students, parents, managers (schools), stakeholders, even local authorities, and central government. The implementation of such policies will have a massive and broad impact (Abidah et al., 2020). One of the impacts is that the learning process must be implemented online during the Covid-19 pandemic (Kemendikbud, 2020). Indeed, the online learning process is the most appropriate mode during the pandemic. However, some studies show that the online learning process does not run effectively and efficiently in terms of technological mastery, student psychology, learning management, and material delivery, resulting in students' low understanding of learning materials (Hong et al., 2021; Irawan et al., 2020; Simamora, 2020). In addition, not all subjects can be easily taught online because each subject has its characteristics, and one of the subjects difficult to teach is mathematics (Ferguson, 2020). Some previous studies have shown that mathematics taught online is challenging for students. For example, research by Lailiyah et al. (2021), suggests that online mathematics learning increases students' anxiety. One of the significant causative factors is cognitive factors. In other words, students' incompetence with mathematical concepts taught online causes anxiety to students during online mathematics learning.

Scientifically, mathematics has many roles in the development of sciences ranging from abstract sciences such as culture, social justice, language, and religion (Habibi & Prahmana, 2021; Ishartono et al., 2019; Larnell et al., 2016; Purpura & Reid, 2016), to technical ones such as in the field of economics, engineering, and architecture (Kent & Noss, 2000; March & Steadman, 2020; Mensik, 2015). Mathematics has characteristics different from those of other sciences; for example, mathematics has abstract working objects (Borwein & Bailey, 2008). Therefore, good thinking ability should be possessed to compose these abstract objects to become a whole concept (Thanheiser & Sugimoto, 2020). In other words, in understanding mathematics, students must be actively involved in constructing their understanding by using their prior knowledge and cognitive ability regarding the concept being studied as it was first discovered to become a meaningful learning process (Agra et al., 2019). Therefore, learning mathematics online becomes challenging. It requires a high level of students' self-regulated learning in constructing their knowledge.

Pintrich (1995) states that self-regulated learning (SRL) refers to an individual's ability to independently determine goals, create and implement strategies, and evaluate and monitor each step used. Other definitions state that SRL is a learning process guided by metacognition ability, strategic action (the ability to make plans, monitor, and evaluate based on predetermined standards), and motivation to learn (Perry et al., 2015; Winne & Perry, 2000; Zimmerman, 1990). In addition, self-regulated learners understand and know their cognitive strengths and weaknesses to be used as a basis for achieving their learning goals, implementing strategies, and monitoring processes (Dweck & Leggett, 1988). Zimmerman (2000) states that a person can be categorized as an SRL when her or his learning process has gone through several phases: the forethought, performance, and self-reflection phases (see Table 1 for details). Based on these explanations and drawn into the context of online mathematics learning, SRL will help students construct their knowledge and understanding of mathematical concepts independently. In offline learning, self-regulated learning improvement should involve specific learning models to maximize the results, especially in online learning, where knowledge transfer must be done remotely (Ulum, 2016; Zimmerman, 1990). One of the online learning models that can be applied is the Flipped Learning model.

Table 1. Characteristics of a person with SRL

Phases	Conditions
Forethought	1. Able to determine learning goals
	2. Able to determine learning strategies
Performance	3. Able to manage the physical and social environment
	4. Able to manage time
	5. Able to do selective monitoring
Self-Reflection	6. Able to do self-evaluation
	7. Able to do casual attribution
	8. Able to adapt the further method

Flipped Learning (FL) is one type of Blended Learning approach where teachers can apply any learning methodology in their classroom (Flipped Learning Network (FLN), 2014; Sukmawati et al., 2020).This learning consists of three stages: the pre-class activity stage, the in-class activity stage, and the post-class activity stage (Roehling, 2018). What distinguishes the FL approach from conventional learning is the application of cognitive achievement. In conventional learning, lower-order thinking skills (LOTS) are applied in in-class activities. Meanwhile, in FL, LOTS is introduced outside the classroom or in pre-class activity so that high cognitive achievement (Higher-order Thinking Skills/HOTS) can be implemented in the in-class activity that is strengthened through enrichment processes in post-class activity (Bergmann & Sams, 2012).

A prominent characteristic of this approach is the availability of learning videos applied at the pre-class activity stage, where students are required to learn the teaching materials through the video provided (Chyr et al., 2017). In this regard, the authors consider that video is not enough to learn mathematics online because students need to do self-mathematical-concept construction. This aligns with Van Oers's (2013) opinion that comprehensive and meaningful mathematical understanding can only be achieved by actively engaging students in self-mathematical-concept construction. Therefore, the application of FL needs to be integrated with a learning medium that can help students do SRL in constructing their understanding of mathematics; one such medium is GeoGebra.

GeoGebra is dynamic geometry software that combines geometry, algebra, and calculus (Fatahillah et al., 2020; Judith & Markus, 2008; Nisiyatussani et al., 2018). This software is commonly used as a medium of calculation and visual media to visualize mathematic abstract working objects (Hall & Chamblee, 2013; Nurcahyo et al., 2021; Puspitasari & Junaedi, 2022). In the Flipped Learning context, the use of GeoGebra can be optimized in terms of its benefits if equipped with investigative questions. This statement is based on Kristanto, Amin, and Khabibah (2016), who suggest that investigative questions can help students independently construct their knowledge on mathematics topics studied.

Previously, many efforts have been made to improve students' SRL in learning mathematics (Kramarski & Gutman, 2006; Marchis, 2011; Qohar & Sumarmo, 2013; Sun et al., 2018). In addition, the results of previous research were examined related to the increase of students' SRL in online learning and mathematics online learning (Kramarski & Gutman, 2006; Sun et al., 2018). However, scant research is related to improving students' SRL in online mathematics learning through GeoGebra integration into the Flipped Learning (GFL) approach.

This situation is critical to be studied for three reasons. First, previous research findings show that, empirically, mathematics taught online becomes more challenging for students in understanding it (Lailiyah et al., 2021). Second, the importance of self-regulated learning during mathematics learning conducted online renders such integration highly relevant. This urgency is in line with the research findings by Cho and Shen (2013) and Sun et al. (2018), who recommend learning independence efforts during the online learning process, which is certainly related to aspects of Self-Regulated Learning. Lastly, as mentioned earlier, the description shows that the Flipped Learning approach still focuses on the use of video during the learning process. Meanwhile, in theory, the big umbrella of the Flipped Learning approach is active learning (Prince, 2004). Therefore, the use of learning videos as part of the initial stage of Flipped Learning is considered not enough to support the nature of active learning in the context of online mathematics learning. Thus, there is still a void of theory about how to apply the Flipped Learning approach based on mathematics learning multimedia which in this context is GeoGebra in improving students' SLR. Since theoretically, the utilization of GeoGebra has a significant role in improving students' understanding of mathematics through online learning (Albano & Dello Iacono, 2019). In addition, there is a lacuna of a study that examine students' SRL improvement efforts through the application of the GeoGebra-integrated Flipped Learning approach. Hence, this study can be an alternative way to improve students' SRL in the online mathematics learning process through GeoGebra-integrated Flipped Learning. It is expected that the findings in the present study can be utilized by practitioners and researchers in the field of mathematics education.

Based on the description above, the following questions are addressed in this study: (1) is the implementation of GFL effective in improving students' SRL during online mathematics learning process? (2) Is the implementation of GFL better at improving students' SRL during the online mathematics learning process compared to FL-based learning and conventional learning? Therefore, this study aims to examine the effectiveness of GFL in improving students' SRL during the online mathematics learning process to answer these questions.

METHODS

Research Design

To fulfill the research purposes in the present study, the method used in this study is an experimental method with a pretest-posttest control group design. It aims to compare the average level of students' self-regulated learning in the group given GeoGebra-integrated Flipped Learning treatment (experiment group 1), conventional Flipped Learning treatment (experiment group 2), and conventional teaching-learning treatment (control group) (see Table 2 for details).

Table 2. Design of the study

Groups	Pretest	Treatment	Posttest
Experiment Group 1	O_1	X_1	O_2
Experiment Group 2	O_3	X_2	O_4
Control Group	O_5	X_3	O_6

Table 2 shows the design of this study, where O_1, O_2, and O_3 are pretest for Experiment Group 1 (Ex 1), Experiment Group 2 (Ex 2), and Control Group (Con), respectively. The O_2, O_4, and O_6 are posttests for all three groups, respectively. Regarding the treatment provided, X_1 represents the GeoGebra-integrated Flipped Learning approach implemented in Experiment Group 1, X_2 represents the conventional Flipped Learning approach implemented in Experiment Group 2, and X_3 represents the conventional teaching-learning approach implemented in the control group.

Participants

A total of 90 students from the mathematics education department from a university in Indonesia participated in this study. The students were from three randomly selected classes from six existing parallel classes, where each class consisted of 30 students. The purpose of selecting the three groups was based on research needs that required an experimental group 1, an experimental group 2, and a control group. Experimental group 1 is a group that uses the GeoGebra-integrated Flipped Learning model, experimental group 2 uses the conventional Flipped Learning model, and the control group uses a conventional learning model. The background of the ninety students was that they were first-year students who were taking calculus courses. Before the research process began, they were informed about the research objective and they were willing to voluntarily participate in the study. The students were treated ethically according to the standard of the American Psychological Association (American Psychological Association, 2017).

Indeed, before the three groups were used as a research sample, the normality test was carried out to see if the three groups were equal or had relatively similar abilities. The data used for the normality test was the value of their semester exam results. Then, the data was analyzed using Shapiro Wilk's normality test formula and it was found that the students' semester value data in all three sample groups was distributed normally. Alternatively, students' ability from all three groups is relatively equal.

Data Collection and Analysis Techniques

The data in this study is quantitative data comprising the results of students' self-evaluation related to their self-regulated learning ability. Therefore, the instrument used in a self-regulated learning questionnaire was modified from the questionnaire developed by Zimmerman (see Table 3). The modification is that the students' points are oriented to their self-regulation in constructing mathematical concepts. The instrument was then validated using Aiken's Coefficient Value (Retnawati, 2016). The validation process involves three experts in mathematics education from two universities in Indonesia. Validation results show that all points submitted in the questionnaire are valid and can be used to measure students' ability of SRL.

The questionnaire uses the Likert Scale with four parameters, namely "1" (strongly disagree), "2" (disagree)," "3" (agree), and "4" (strongly agree). The authors proposed two types of questionnaires, one for the pretest and another one for the posttest. The questionnaires have the same aspect with different orientations of the condition. For the pretest questionnaire, the questions refer to their SRL condition before the learning process occurred. For the posttest questionnaire, the questions refer to their SRL state after the learning process (treatment). The time used by the students to complete the questionnaire was 30 minutes. The students had plenty of time to think about their answers. In addition, the researchers also directed the students to answer the questions carefully to minimize the possibility of gambling.

Data analysis techniques are based on the efforts to answer research questions, namely the application of Normalized Gain (N-Gain) Score techniques to see the effectiveness of the GFL, FL, and conventional-based learning model implementation in improving students' SRL during the online math learning process, and descriptive statistic techniques to describe which is better between experimental group 1, experiment group 2 or control group in improving students' SRL during the online mathematics learning process.

Table 3. The aspects of the modified SRL questionnaire from Zimmerman (1990)

Aspects	Conditions	Statements Number
Forethought	1. Able to determine learning goals	(1), (13)
	2. Able to determine learning strategies	(5), (15), (16)
	3. Able to independently seek needed information	(12), (14)
	4. Able to independently analyze learning difficulties	(3), (6)
	5. Able to independently find out the solution for the learning difficulties	(2), (4)
	6. Able to do self-mathematical-concept construction independently in learning mathematics	(9), (11), (23)
Performance	7. Able to manage the context of the physical and social environment	(10), (19)
	8. Able to manage time	(7)
	9. Able to do selective monitoring	(8)
Self-Reflection	10. Able to do self-evaluation	(17), (22)
	11. Able to do casual attribution	(18)
	12. Able to adapt the further method	(20)
	13. Able to double-check the work	(21), (22)

Research Procedures

The present study used three sample groups with three different treatments for each group: GeoGebra-integrated Flipped Learning (GFL) approach, conventional Flipped Learning (FL) approach, and conventional teaching-learning approach. Specific to GFL and FL, the application of the two approaches is the same: pre-class, in-class, and post-class. What distinguishes them from both is the content at the pre-class activity stage of both the GFL and FL approach. In the FL approach, as Bergmann and Sams (2012) described, there is an emphasis on learning videos in pre-class activities, where students are expected to learn from the learning videos. Meanwhile, in the GFL approach, the use of learning videos is replaced by the use of GeoGebra as a medium of mathematical learning (see Figure 1). GeoGebra is equipped with investigative questions, which act as triggers for students to understand the materials taught. In the context of this study, they introduce the graph of a quadratic function by manipulating the GeoGebra-based mathematical learning medium to answer the investigative questions given.

In Figure 2, it can be seen that the medium gives three sliders that students can manipulate to be able to change the coefficients and constants in the standard equation of quadratic functions. One example of the investigative questions given is, "if you move the slider-c to the right and left, what happens to the graph of the quadratic function?" By answering the question, students are expected to understand that slider-c, which represents a constant in a standard equation of quadratic function, determines the intersection point between the graph of a quadratic function and y-axis (if the graph is vertical) or the x-axis (if the graph is horizontal), as the same as the group that gets a learning model with a conventional teaching-learning approach.

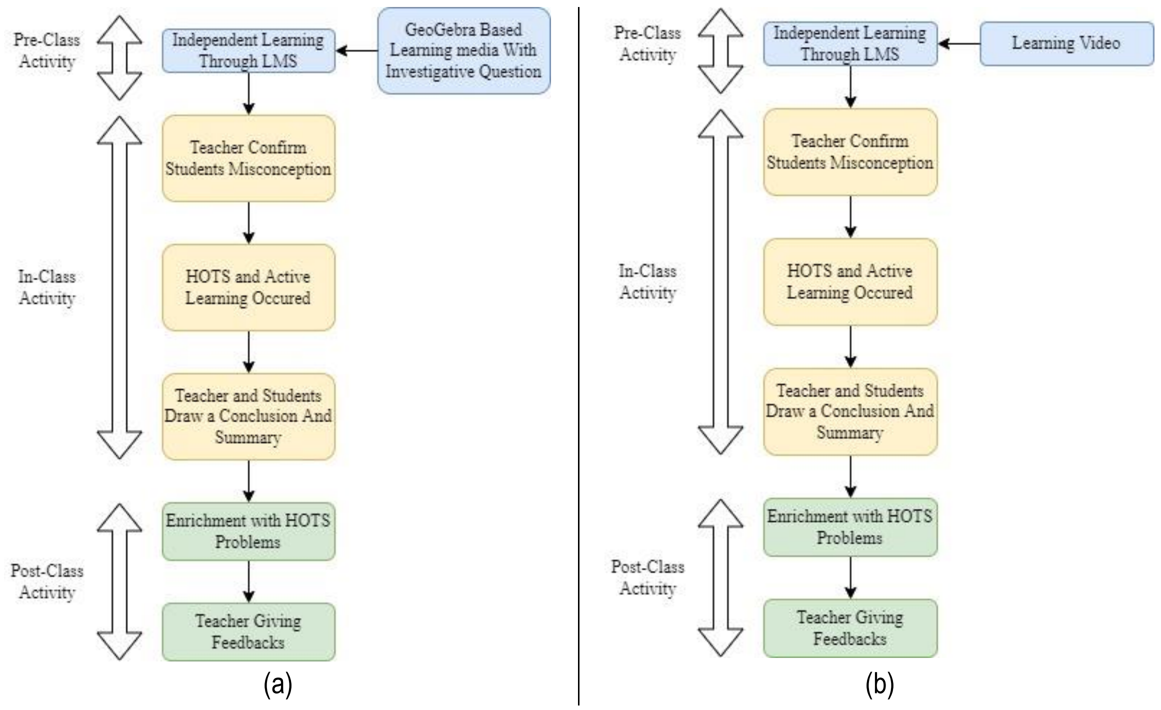

Figure 1. The design of (a) GFL Model and (b) FL Model

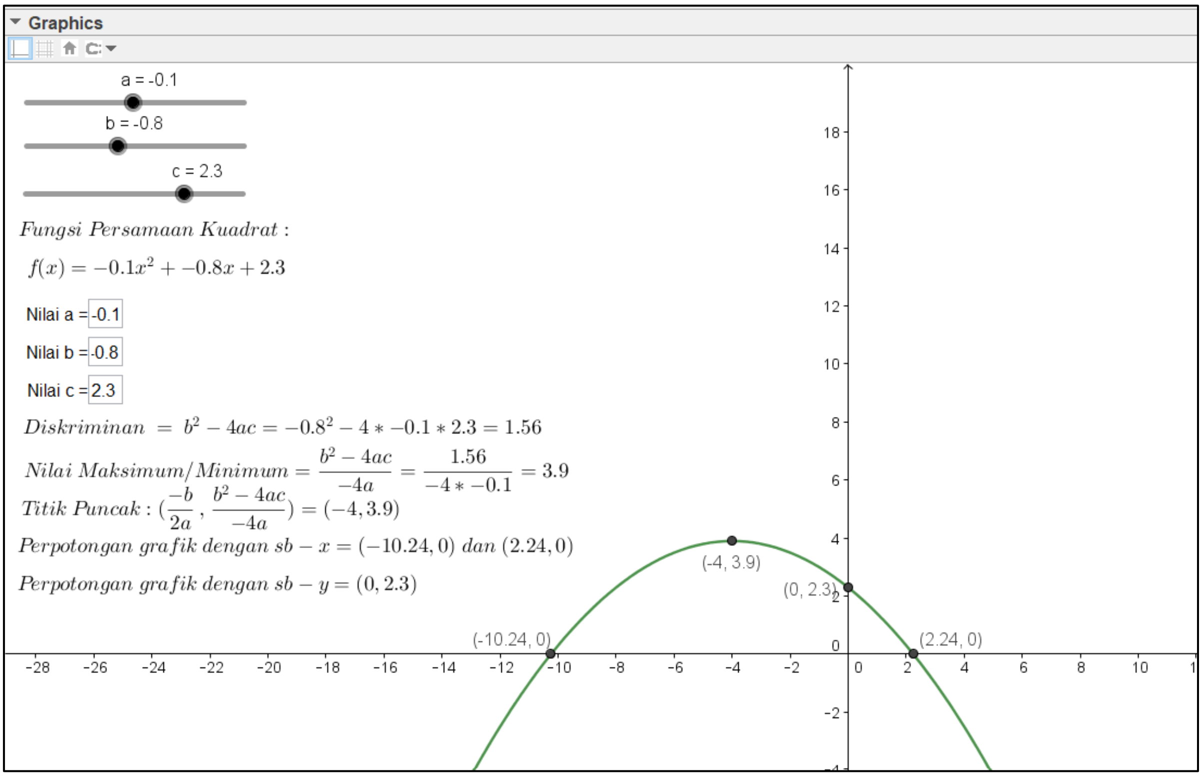

Figure 2. GeoGebra-based mathematics learning medium

The research was conducted online for six meetings (a half-semester) from May to July 2021. Each meeting was given the same treatment in experimental groups 1, experiment 2, and control groups (see Figure 1). For experimental group 1, each learning process was divided into three parts, as described earlier. In pre-class activities, teachers provided students with GeoGebra-based learning media uploaded online, and teachers could monitor it. With this media, it is expected that students can manipulate it and answer all the investigative questions given to construct their understanding. In the in-class activity, the teacher began to confirm the knowledge acquired by the students from the given GeoGebra-based learning media by asking the same question related to the learning materials. Once the teacher validated the correct knowledge, the teacher commenced a HOTS-based learning activity deepening their understanding of the material. At the end of this activity, the teacher and students summarized the concepts they have learned. After an online, face-to-face meeting had been accomplished, the learning process proceeded to the next phase, the post-class activity where the teacher gave students some HOTS-based problems to enrich their understanding, which ended with the provision of feedback by the teacher.

The same procedure was applied to experimental group 2. As previously explained, in the pre-group activity stage, students were given learning videos to watch and understand. As for conventional groups, the material was directly taught and introduced in face-to-face sessions.

RESULTS AND DISCUSSION

Result

Normalized Gain (N-Gain) Score on the GFL Implementation

The purpose of using the N-Gain score in this study is to test the effectiveness of applying a learning method (Bao, 2006). In this research, this refers to the application of GFL, FL, and conventional-based learning models in improving students' SRL during the online mathematics learning process. The N-Gain model used in this section is the Average of N-Gain model because the researchers know the response data from students so that it can be analyzed directly by researchers. Next, the tightening of the level of effectiveness in the N-Gain analysis, authors refer to categorization by Hake (2002), which divides categorization into four categories which are (1) "Effective" with Gain values above 76%, (2) "Effective Enough" with Gain values between 56% and 76%, (3) "Less Effective" with Gain values between 40% and 56%, and (4) "Ineffective" where the Gain value is below 40%.

The analysis phase began by grouping student response data according to three assessed aspects: forethoughts, performance, and self-reflection. Then the pretest and posttest averages of the students' responses in each aspect were calculated using the Average of N-Gain formula (see Table 4 for the result).

Table 4. Result of Normalized Gain (N-Gain) Score

Aspects	Experiment Group 1			Experiment Group 2			Control Group		
	Pretest (M)	Posttest (M)	N-Gain	Pretest (M)	Posttest (M)	N-Gain	Pretest (M)	Posttest (M)	N-Gain
Forethoughts	1.65	3.28	69%	1.76	3.21	63%	1.71	3.26	67%
Performance	1.85	3.42	71%	1.97	3.16	56%	1.91	3.10	52%
Self-Reflection	1.70	3.30	69%	1.92	3.27	64%	1.92	2.88	45%
Average	**1.73**	**3.33**	**69%**	**1.88**	**3.21**	**61%**	**1.85**	**3.08**	**54%**

Note: M = Mean

Table 4 shows that the N-Gain grades of the experimental group 1 for all aspects are between 56% and 76%, which means it can be categorized as "Quite Effective". The same condition is also obtained in the second experimental group, where all aspects are categorized as "Quite Effective".

Meanwhile, in the control group, only aspects of Forethoughts are categorized as "Quite Effective", while others are "Less Effective".

Descriptive Statistical Test Result

Descriptive statistical tests describe generalizations of research results from research samples used (Fisher & Marshall, 2009). In this research, the samples are experiment group 1, experiment group 2, and control group. To begin the analysis, the authors determined pretest and posttest grades based on each student's response to each aspect assessed. The author calculated each student's N-Gain value based on the pretest and posttest grades. That data was then analyzed and described by the author. Next, the data was analyzed using Cohen's D effect size formula to measure how large the effect between the experimental and control classes was based on the mean (Peng & Chen, 2014). Sawilowsky (2009) divides Cohen's d effect size into six categories: "Very Small" (0 - 0.01), "Small" (0.01 - 0.2), "Medium" (0.2 - 0.5), "Large" (0.5 - 0.8), "Very Large" (0.8 - 1.2), and "Huge" (1.2 - 2.0). The analysis was carried out using SPSS version 23 (see Table 5 for the result).

Table 5. Descriptive statistic test result based on N-Gain score per aspect

Aspects	Experiment Group 1			Experiment Group 2			Control Group	
	Mean	**SD**	d_1	**Mean**	**SD**	d_2	**Mean**	**SD**
Forethoughts	0.692	0.13478	0.14	0.6322	0.10332	0.24	0.6735	0.13860
Performance	0.7148	0.18895	0.72	0.5609	0.26067	0.12	0.5245	0.32204
Self-Reflection	0.6969	0.13937	1.40	0.6424	0.19887	0.93	0.4587	0.19552

Note:
*d*1: effect size between experiment group 1 and control group
*d*2: effect size between experiment group 2 and control group

Table 5 shows that in experimental group 1, the Self-Reflection aspect has the most significant effect size of 1.40, categorized as having a huge effect size, followed by aspects of Performance and Forethoughts which obtains 0.72 and 0.14 categorized "Large" and "Small" respectively. Furthermore, in experimental group 2, the largest d value is also found in the self-reflection aspect, categorized as "Very Large". However, the second position is occupied by aspects of Forethoughts which obtain a d value of 0.24 or "Medium". The lowest value is obtained by aspects of performance, which obtains a value of 0.12, categorized as "Small".

The authors only analyzed students' responses from the posttest to determine which model improves students' SRL ability. The responses were averaged per aspect and categorized into Low($\bar{x} \leq 1$), Moderate $(1 < \bar{x} \leq 3)$, and High $(3 < \bar{x})$. Once categorized, the frequency was calculated and its proportions were analyzed.

Table 6. The proportion of students' SRL level categories

Categories	Forethoughts			Performance			Self-Reflection		
	EG 1	**EG 2**	**CG**	**EG 1**	**EG 2**	**CG**	**EG 1**	**EG 2**	**CG**
High	77%	57%	47%	70%	50%	40%	70%	50%	30%
Moderate	23%	43%	53%	30%	50%	60%	30%	50%	70%
Low	0%	0%	0%	0%	0%	0%	0%	0%	0%

Note:
EG 1 : Experiment Group 1
EG 2 : Experiment Group 2
CG : Control Group

Table 6 shows the frequency of students' SRL-level category based on posttest results after treatment in each sample group. No group obtains the Low category in all aspects of SRL. When compared per aspect as in the Forethoughts aspect, Experiment Group 1 had the largest proportion of High categories compared to the other two groups. The same is true in the Performance and Self-Reflection aspects, where the proportion of high categories owned by the group in all three aspects is considered above 70%, followed by Experiment Group 2 and Control Group. Both groups have the same position in all aspects.

Discussion

The present study analyzes how effective the implementation of the GeoGebra-integrated Flipped Learning model improves students' SRL ability during online mathematics learning. The comparison is with the Flipped Learning model and the conventional learning model. The findings raise some issues and implications for further discussion regarding whether the implementation of the GFL model is classified as effective in improving students' SRL during online learning and whether the implementation of GFL is better than the other two models in improving students' SRL. The authors begin the discussion by addressing the effectiveness of the GFL model implementation and then compare the effectiveness of the GFL model implementation to the other two models.

The Effectiveness of GFL Implementation in Improving Students' SRL Ability

The current study indicates that implementing the GeoGebra-integrated Flipped Learning during the online math learning process effectively improves students' SRL based on the three aspects assessed. It is shown by the N-Gain score in the "Quite Effective" category. The same thing happened in the experimental group 2, of which the three aspects assessed were categorized as "Quite Effective." However, if reviewed more deeply, the N-Gain score obtained in experimental group 1 is higher than that of the experimental group 2. For example, in the Forethoughts aspect, this aspect assesses students' ability to make plans that they will later achieve. In this aspect, the N-Gain score achieved in experimental group 1 was at 69% points, or 6% different from the score obtained in experimental group 2. It can happen because the role of GeoGebra-based calculus learning media (with investigative questions) used by lecturers in the experimental group 1 during the application process can be lighter for students to be able to make planning related to what steps should be used in the process of answering investigative questions given from the media. In addition, students already have the learning capital from the activities they get in the pre-class activity phase during in-class activity. Therefore, students can make plans and strategies in solving problems provided by lecturers in the in-class activity.

An interesting finding from this study is that aspects of Forethoughts in the control group had N-Gain values that outperformed the experimental group 2. Students are not actively involved in the pre-class activity process in the second experimental class and only see learning videos. The statement is in line with the research findings by Lackmann et al. (2021) revealing that the application of learning videos in blended learning did not significantly affect student engagement in their study process. Thus, the inactivity of students in the learning process makes them weak in making learning plans. It is not easy to pursue in the in-class activity phase because, in this phase, the quality of the learning process has improved towards learning with an active learning and HOTS approach. On the other hand, a control group that uses conventional learning models provides ample space for teachers to prepare students from scratch to make a learning plan on the calculus matter being taught. Therefore, it is very reasonable when the N-Gains score of the control group is higher by 0.04 than the experimental group 2.

The Performance aspect became the highest N-Gain score in the experimental group 1. It is natural because students prepared carefully in constructing their knowledge independently related to materials taught through GeoGebra-based learning media with investigative questions that have been given in the pre-class activity phase. This condition is much better than the other group's performance aspect. For example, in a control group where students do not have a large space to construct their knowledge during the online learning process, they rely only on lecturer explanations on face-to-face activities. So, they cannot manage their time to study since they do not know which learning materials to be studied. It is commonly known that college students must manage their time to accommodate all their learning needs (Britton & Tesser, 1991; Misra & McKean, 2000).

Finally, related to the Self-Reflection aspect, the GFL model also provides ample space for students to evaluate their learning process. One of them is at the pre-class activity stage, where students must answer all investigative questions given. In the process, students design the problem-solving strategies provided and conduct trial and error while optimizing GeoGebra-based mathematical learning media. A trial-and-error process is a tangible self-reflection aspect as part of SRL ability. In the context of learning, of course, self-reflection becomes vital in the learning process where students are given time to reflect on their results and steps in solving a problem (Lew & Schmidt, 2011).

Comparison of Effectiveness Rate of Implementation of GFL Model with Two Other Models in Improving Students' SRL Ability

From the results obtained, this study also indicates that the GFL model improves students' SRL ability during the online mathematics learning process compared to two other model implementations. This can be seen from the data presented in Table 5, which shows that the Cohen's *d* effect size value of the experimental group 1 against the control group in each aspect is higher than Cohen's *d* effect size of the experimental group 2 except for the Forethoughts aspect. Based on Table 5, the Forethoughts aspect for experimental group 1 has a lower *d* value than the experimental group 2. The d value for the Forethoughts aspect in the control group is higher than that in the experimental group 2. Thus, it slightly differs from the value of d in the experimental group 1 and the control group. However, the d value only gives an idea of the extent of the differences between the experimental and control groups.

In addition to being based on effect size results, other analytical results that can be used to emphasize improving students' SRL than the three learning models applied can be seen from Table 6. The table shows that experimental group 1 has the largest proportion in the "High" category in every aspect of the SRL, where nothing is less than 70%. Next was followed by the experimental group 2 and the control group, which were in second and third positions, respectively. The data was taken only on student responses obtained in the posttest phase. The posttest phase measures the results of student response after following the learning with treatment by each group. Therefore, it is not surprising if, in Table 6, there is not a single aspect that gets the category "Low". It can be concluded that the application of the GFL model is better in improving students' SRL during the online math learning process than the application of the other two models.

Online math learning is a specific challenge for teachers, especially at the college level, where the math material taught is entirely abstract (Dahl, 2018). In addition, the process of transferring knowledge from lecturers to students is also limited due to technical factors such as lack of proficient lecturers in running computer-based facilities, facilities that do not meet either in the students or lecturers environment, and learning environments that may not be standard and comfortable to study (Juan et al., 2011). Therefore, the success of the mathematical learning process conducted online depends on the quality of the student in independently constructing his knowledge. Therefore, self-regulated learning skills become very important to be improved.

During the Covid-19 pandemic, several studies examined making online mathematics learning more effective and efficient (Halil, 2020; Mustakim, 2020). Online learning can be effective and efficient when the learning process can get as many learning achievements based on the highest cognitive level (Ergen & Kozat, 2018; Subakri & Annizar, 2021). Therefore, through the results of this study, the authors try to make a contribution based on an experimental study by showing one of the alternative ways to make online learning more effective and efficient through the integration of GeoGebra into the Flipped Learning approach, which effectively improves students' SRL in conducting self-mathematical-concept construction during online learning.

Based on many articles in the literature that the authors have reviewed, there are still no efforts to improve students' SRL in self-mathematics-concepts construction during online learning through the integration of GeoGebra into the Flipped Learning approach. However, by observing the aspects of SRL improvement through the Flipped Learning approach, the results of this study strengthen the previous research conducted by Zheng, Ward, and Stanulis (2020), indicating that students tend to have a high SRL during the learning process based on the Flipped Learning approach. In addition, the results of this study also support the results of research by van Alten, Phielix, Janssen, and Kester (2020), which demonstrates that the application of Flipped Learning approach during online learning can help students to increase their SRL level in understanding the topics taught to them. Furthermore, regarding the use of GeoGebra in improving students' SRL in learning mathematics, the results of this study also support previous research such as the results of research from Zetriuslita, Nofriyandi, and Istikomah (2020) and Hidayati and Kurniati (2018), which suggests that the use of GeoGebra can improve students' SRL in learning mathematics. The results of this study offer a potential contribution to theoretical research that examines the role of GeoGebra in improving students' Self-Regulated Learning ability in the process of constructing their knowledge independently. GeoGebra as a learning medium has a vast potential to be developed to help students investigate a concept so that students understand the concept independently and as instructed (Asmar & Delyana, 2020). In addition, this study also found the role of GeoGebra, which integrates investigative questions, in helping students get used to self-reflection while constructing their knowledge independently. Of course, this aspect is critical in learning mathematics, where students must be carefully measured to ensure that the steps taken by students are on the right track (Zimmerman et al., 2011).

Indeed, there is still much space that can be further researched from the results of this study. One area is related to the level of education of the research subjects. In this study, the subjects' education level involved only university students. Therefore, future research can involve subjects from different levels of education, such as elementary to secondary school, so that scope of the impact of applying GeoGebra-integrated Flipped Learning in improving students' SRL in conducting self-mathematical-concept construction during online learning could be broadened.

From the results of this study, it is expected that benefits will be provided for mathematical education practitioners in demonstrating how to improve students' self-regulated learning in conducting self-mathematical-concept construction during online learning through a GeoGebra-integrated Flipped Learning approach. It can help online mathematics learning to run more effectively and efficiently.

CONCLUSION

The findings of the present study suggest that based on the N-Gain score in every aspect, the integration of GeoGebra in the Flipped Learning model is quite effective in improving students' SRL during online mathematics learning. In addition, it was also found that based on descriptive statistical analysis and Cohen's d effect size, the application of the GeoGebra-integrated Flipped Learning model is better than the Flipped Learning model, which is only based on video learning. Therefore, the present study recommends the use of GeoGebra-integrated Flipped Learning model to improve students' SRL ability in mathematics online learning.

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Declarations

Author Contribution	:	NI: Conceptualization, Writing – Original Draft, Editing and Visualization. AN: Validation and Review Formal Analysis. MW: Validation and Review Formal Analysis. HJP: Review Formal Analysis and Language Proofreading. MH: Visualization, Editing and Templating.
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