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EFFECTIVENESS OF FLIPPED CLASSROOM MODEL THROUGH MULTIMEDIA TECHNOLOGY IN IMPROVING STUDENTS' PERFORMANCE IN DIRECTED NUMBERS

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ABSTRACT

The recent globalisation and the emergency of COVID-19 require a teaching and learning environment that encourages the use of technology. Through a mixed-method design and an action research approach, this study investigated the effectiveness of a flipped classroom model through multimedia technology in improving students' performance in directed numbers, given the difficulty and misconceptions of students in this mathematical concept. A total of 30 Year 9 students conveniently sampled from one of the secondary schools in Brunei Darussalam served as participants. The action taken involved a pretest, intervention, posttest, and interviews. The results of the paired sample t-test revealed that students' performance in directed numbers significantly improved after the flipped classroom intervention. Students had positive perceptions of the flipped classroom model as it encouraged their readiness, participation, and motivation. Challenges such as time constraints and distractions when studying from home were reported. These results imply that amid COVID-19, a flipped classroom through multimedia technology can be an effective and alternative way of teaching and learning directed numbers. It has the potential of encouraging student-centred learning and creativity, which are vital in teaching and learning mathematics.

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1. INTRODUCTION

Education in the 21st century has witnessed several changes. Approaches that encourage more student-centred compared to teacher-centred instruction continue to be developed and integrated into teaching and learning. Globalisation, the development of technology, and the emergency of COVID-19 have shown that traditional approaches to teaching and learning may not meet current educational needs and goals (Jamil et al., 2022;

Shahrill, Noorashid, et al., 2021; Shahrill, Petra, et al., 2021). This has called for a need to constantly create instructional environment that encourages the use of technology (Bishop & Verleger, 2013).

In responding to the changing needs of education, one of the approaches that have attracted recent research attention is the flipped classroom model. Baker (2000) introduced this approach to instruction as a component of blended and inquiry-based instruction. It is an approach in which homework and classroom activities are interchanged Ash (2012), such that students study instructional materials at home with their peers and teachers, followed by the teacher giving feedback and engaging in directed conversations during class time (Lin & Chen, 2016; Say & Yildirim, 2020). It exposes the students to study and understand instructional materials out-of-classroom, and in the classroom, do activities that support learning with the help of the teacher (Moravec et al., 2010). Students mainly study and master instructional materials through multimedia technology by watching videos, listening to podcasts, and reading e-books (Balu, 2020; Dominic-Ugwu & Nonyelum, 2019).

Using a flipped classroom model is associated with high students' performance, motivation and retention (Busebaia & John, 2020; Say & Yildirim, 2020; Sirakaya & Ozdemir, 2018), and this is irrespective of subject areas and educational level (Strelan et al., 2020). It promotes student-centred learning, leading to student engagement, active participation, and self-directed learning (Pierce & Fox, 2012; Qader & Yalcin Arslan, 2019). Students can learn instructional materials at their own pace, ensures effective use of classroom time because most of the instructional tasks are done by the students at home, and the classroom time is used to clarify the misconceptions of students (Fulton, 2012; Hew & Lo, 2018; Matzin et al., 2013). Given that a flipped classroom model encourages collaboration among their peers, high-ability students can assist low-ability students in constructing their knowledge on a given topic (Ferreri & O'Connor, 2013; Nielsen et al., 2018).

Using a flipped classroom model encourages students to think creatively within and outside the classroom (Herreid & Schiller, 2013). However, the approach to teaching and learning has some disadvantages. Teachers are unable to know if students learned instructional concepts at home. The lack of internet and other devices such as mobile phones, tablets and computers that make learning possible are other notable challenges (Jenkins, 2012). Other demerits of the flipped model include the high cost that comes with technology and the failure to create an environment where students can ask questions when learning at home (Jenkins, 2012). Despite these demerits, a flipped classroom model inverts the traditional model of instruction. It has the possibility of increasing student readiness as the learning content is introduced to students before the physical class. This allows teachers more instructional time to guide students through practical, active, and innovative ways of learning.

Previous studies have emphasised the need to use multimedia technologies in flipped classrooms and provide the technical support needed for such multimedia (Oliveira, 2018). Integrating multimedia in flipped learning has gained considerable relevance in teaching and learning. Therefore, previous research attempts have focused on technological and conceptual improvement in using a flipped classroom model, especially on monitoring student learning while they are at home (Jovanović et al., 2017). A flipped classroom model does not necessarily need to be implemented in an online platform, as it can also be done using multimedia technologies where text, visuals, animation, video, and sound can be merged to improve teaching and learning (Abdurasulovich et al., 2020). Since multimedia triggers multiple senses of audiences at a time, using various media in a flipped classroom model can produce conclusive results in teaching and learning (Rajendra & Sudana, 2018; Yohannes et al., 2016). Using multimedia in a flipped classroom serves as a varied source

of information for students, making learning content accessible to students based on their preferences (Aprianto et al., 2020; Cevikbas & Kaiser, 2020).

How multimedia is used in a flipped classroom model to meet student needs and how students handle multimedia resources are also essential to determine the success of the flipped classroom methodology. Oliveira (2018), for example, indicated that flipping the classroom is not a sufficient condition for improvement in student learning and engagement. However, how instructional resources in different formats reach the students and how well students can understand such resources are relevant. Although student perceptions about flipped learning model are generally positive, students who have positive perceptions are those who can access instructional materials on time and without difficulty. At the same time, they prefer traditional teaching methods that are more interactive and learner-centred compared to a flipped classroom model (Oliveira, 2018; Yohannes et al., 2016).

To this end, this study investigates the effectiveness of using multimedia technology in a flipped classroom model in improving students' performance in directed numbers. Directed numbers or integers have both direction and size, with one direction being positive and the other negative. For example, in 4-(-3), both 4 and (-3) are directed numbers with the 4 and (-3) being positive and negative, respectively. Having a sufficient understanding of these numbers are applicable in everyday life (Fuadiah & Suryadi, 2017). They are helpful in reading temperature. A temperature of (-10) degrees means that it is 10 degrees away from and less than 0, suggesting a high level of coldness compared to a temperature reading of 10 degrees.

Understanding directed numbers is also helpful in profit and loss. It helps to know how less or more can be done to achieve satisfactory results in all aspects of life. Profit is denoted by positive numbers in business transactions, while negative numbers indicate losses. Understanding directed numbers helps to check account balance (Makonye & Fakude, 2016). If money is added to one's account and there are adequate funds in the account, it is denoted by a positive number. In contrast, money withdrawn from one's account is represented by a negative number. In the health sector, directed number is also applicable. Normal blood pressure will record a positive number, while blood pressure below normalcy can be negative. This suggests that directed numbers are significant in every life, and the failure of students to have a good understanding of such numbers may cause serious challenges when applying such numbers in their daily activities.

Students have inadequate understanding and several misconceptions, despite the relevance of directed numbers (Bofferding, 2014; Lamb et al., 2012; Vlassis, 2008). Mostly, they are unable to differentiate between a negative sign used as an operation and one used as a symbol (Lamb et al., 2012). This creates difficulties for them when performing operations involving directed numbers. Student difficulty in directed numbers and other mathematical concepts exists in Brunei Darussalam (hereafter referred to as Brunei). Previous research has consistently reported that students have difficulty understanding algebraic expressions, fractions, simultaneous, linear, and quadratic equations (Chong et al., 2022; Hamid et al., 2013; Japar et al., 2021; Johari & Shahrill, 2020; Rosli et al., 2020; Sarwadi & Shahrill, 2014; Shahrill, 2018). In most studies, the predominant cause of low performance was attributed to factors such as over-reliance on past examination questions, anxiety and stress, and teaching approaches (Latif, 2021; Salam & Shahrill, 2014; Shahrill, 2018; Zakaria et al., 2013) and inadequate understanding and misconceptions about directed numbers (Levison, 2016). Despite these gaps, interventions to improve students' understanding and performance in directed numbers are scarce.

Therefore, this study that provides a flipped classroom intervention to evaluate its effectiveness in improving students' performance in directed numbers is timely. For the studies that focused on secondary schools in Brunei, emphasis was placed on geography

(Nawi et al., 2015) and history (Latif et al., 2017). The paucity of studies that focused on secondary school mathematics did not consider directed numbers (Manjanai & Shahrill, 2016; Toh et al., 2017). Therefore, more studies are necessary to develop a more in-depth analysis of the effects of the flipped classroom model in the teaching and learning of secondary school mathematics. This present study provides a flipped classroom intervention to assess its efficacy in improving student performance in directed numbers using secondary school students in Brunei. The following research questions were answered: (1) What is the effectiveness of a flipped classroom model through multimedia technology in improving students' performance in directed numbers? (2) How do students perceive a flipped classroom model through multimedia technology as an instructional option?

2. METHOD

This study adopted a mixed-method design with an action research approach where both quantitative and qualitative data were collected sequentially (Creswell & Creswell, 2017). The quantitative data were collected through achievement tests before the qualitative data, which was collected through interviews. Since this study sought to provide a flipped classroom intervention to address student difficulty in directed numbers (Avison et al., 1999; Mertler, 2013), the action included a pretest, an intervention, and a posttest.

Through a conveince sampling, 30 Year 9 students were selected. They were from one of the government secondary schools in the Belait District of Brunei. The selected school had two Year 9 classes. Class A consisited of 14 students (five males and nine famales), while Class B consisted of 16 students (seven males and nine feamles). The students in both classes served as participants for this study. They were used because directed numbers are taught at that grade level, and for this reason, providing intervention on the concept was feasible. Both classes consisted of students with mixed abilities. Students in both classes were combined to provide the intervention at the same time.

There were two instruments used to collect data: achievement tests and a structured interview guide. The achievement tests involved a pretest and a posttest on directed numbers. The pretest was used to assess the entry behaviour of students before the intervention was provided, while the posttest was used to evaluate students' performance after the intervention. Both tests consisted of similar questions with the same level of difficulty. They involved four categories of questions that required students to find the magnitude (2-questions), order (2-questions) add and subtract (2 questions), and solve temperature related questions (2-questions) involving directed numbers. The duration for each achievement test was 30 minutes. The total score for each of the achievnment test was eight marks, with one mark for each question.

The structured interview guide asked participants their perceptions of the intervention provided. The main question that was asked in the interview is "How do you perceive the teaching and learning of directed numbers in the flipped classroom through multimedia technology? A total of six participants availed themselves for the interviews. Six participants were suitable for the interview because the interview data was saturated afer the sixth participant. That is, we noicted that from the seventh participant who was interviewed, no new information was discovered on our study variables (Saunders et al., 2016). To improve the content validity of the tests, specific lesson objectives were set for each of the areas in the test. A table of test specification was developed to ensure that all eight questions evenly covered all the areas of the lessons. The questions for the interview were given to four mathematics teachers who had more than 12 years of teaching experience. These experts

evaluated the measurement quality of the questions. All suggestions from these experts were inculcated before administration.

Ethical clearance was obtained from the Faculty's Ethics Committee of the University. Permissions were also obtained from school leaders through formal approval letters. Students and parents also completed informed consent forms to indicate their willingness to serve as participants and allow their children to participate in this study, respectively. The information and identities of the students have been kept confidential and anonymous. The pretest was conducted before the main intervention. The test was organised online through a WhatsApp group chat, where the pretest was posted. The students were given 30 minutes to answer all eight questions. They posted all their answers in a word file on the same platform, which we downloaded and scored. Second, the lesson intervention, which involved a flipped classroom teaching and learning of directed numbers, was implemented. Participants received a pre-class video lesson sent to them through the WhatsApp group chat to learn at home. Two YouTube videos on directed numbers created by Math Antics (2014a, 2014b), were edited and used in the intervention. The duration of the videos was 13 minutes. The video lessons covered definitions, positive, negative, addition, subtraction, and representing directed numbers on a number line. All instructions regarding the video lesson were also provided in the group chat.

Students were asked to form groups of three to four members to prepare group presentations based on specific areas. They were given a week to learn the video lesson and prepare for the in-class presentations. After that, we had a collaborative and activity-based face-to-face classroom session. Each group of students had a 15-minutes presentation to share what they had learned based on specific areas on directed numbers and were given a manila card to write their presentation answers. After each presentation, there was a question-and-answer section. The first author addressed and clarified all student misconceptions and learning gaps based on their presentations and the lesson task they learned at home. The first author facilitated all presentations. Figure 1 illustrates the scenes of the activity-based in-class session of the flipped classroom intervention.

Figure 1. Scenes of the activity-based in-class session of the flipped classroom intervention

The students were actively involved in the activity-based instruction during the in-class intervention (see Figure 1). They satisfactorily prepared their presentations using manila cards and presented their answers to the assigned tasks in front of the whole class. They were able to respond to each of their peers' questions based on their presentations. The facilitator gave minimal guidance and comments since the students had completed the tasks individually and in groups at home before the in-class presentations and interaction. After the intervention, the posttest was conducted on the same day, and all 30 students were combined to take the test. There was a tranquil testing environment, and instructions regarding the posttest were given. The posttest lasted for 30 minutes, after which all scripts were collected, marked, and recorded. The pretest and posttest scores were entered into

SPSS, which aided the analysis. Data cleaning was performed to address all missing values and outliers. A paired sample t-test was performed to compare the pretest and posttest scores to check and test for a mean difference. Since the paired sample t-test is a dependent test, the dependent variable was the pretest and posttest scores. This statistical tool was used because pretest and posttest scores (interval data) from the same group of students were analysed before and after the intervention to examine performance (Coman et al., 2013). Additionally, the data for pretest ($p=0.677>0.05$) and posttest ($p=0.561>0.05$) were approximately normally distributed (Fisher & Marshall, 2009). Therefore, the paired sample t-test was suitable to determine the effectiveness of the flipped classroom intervention. The transcribed interview data were analysed thematically. In the thematic analysis, we farmiliarised ourselves with the data before generating initial codes. Potential themes were searched, reviewed and defined before producing the interview report (Braun & Clarke, 2012).

3. RESULT AND DISCUSSION

3.1. Effectiveness of flipped classroom model in improving students' performance in directed numbers

The overall results showing the efficacy of the flipped classroom intervention in improving students' performance in directed numbers are presented in Table 1.

Table 1. Paired sampled t-test between pretest and posttest scores

	Descriptive Statistics					95% Confidence Interval of Mean Difference					
	Mean	SD	Mean difference	SD	Std. Error	Lower	Upper	t	df	Sig. (2-tailed)	Cohen d
Pretest	5.67	1.90	0.90	2.01	0.366	0.051	1.550	2.18	29	0.037	0.4
Posttest	6.57	1.31									

N = 30, SD = standard deviation; mean difference is significant if sig<0.05

The results of the paired sample t-test show that students' performance in the posttest (mean = 6.57, SD = 1.31) is significantly higher than in the pretest (mean = 5.67, SD = 1.90) with $t(29) = 2.18$, $p = 0.037<0.05$ (see Table 1). This suggests that performance in directed numbers significantly improved after the flipped classroom intervention. From the Cohen's d value of 0.4, it is observed that approximately 40% of students' performance in directed numbers is accounted for by the intervention provided, which signifies a medium effect. Since we are particularly interested in how students improved in answering each of the questions correctly, Figure 2 illustrates the number of participants who answered correctly in both tests.

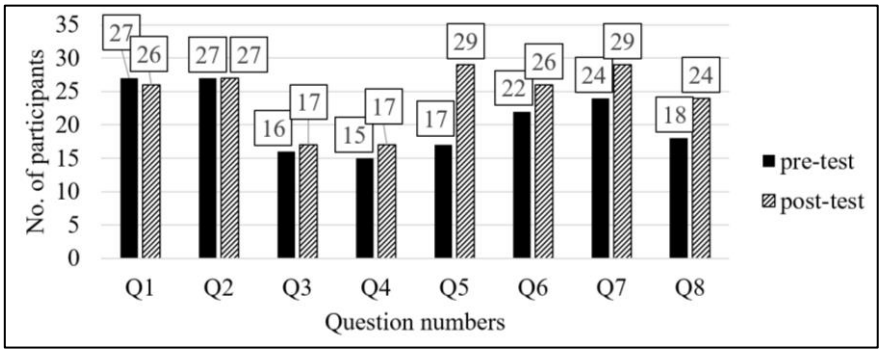

Figure 2. Number of correct responses of participants

Of the eight questions, the participants improved their correct responses for six questions, from questions 3 to 8 (see Figure 2). The number of participants who improved their pretest scores at the posttest level ranges from 1 to 12, with the most significant change of 12 participants for question 5. Participants did not improve their pretest and posttest scores (27 marks for each) for question 2. For question 1, the pretest score (27 marks) is slightly higher than the posttest score (26 marks). We present specific errors and misconceptions based on the eight questions starting from Figure 3.

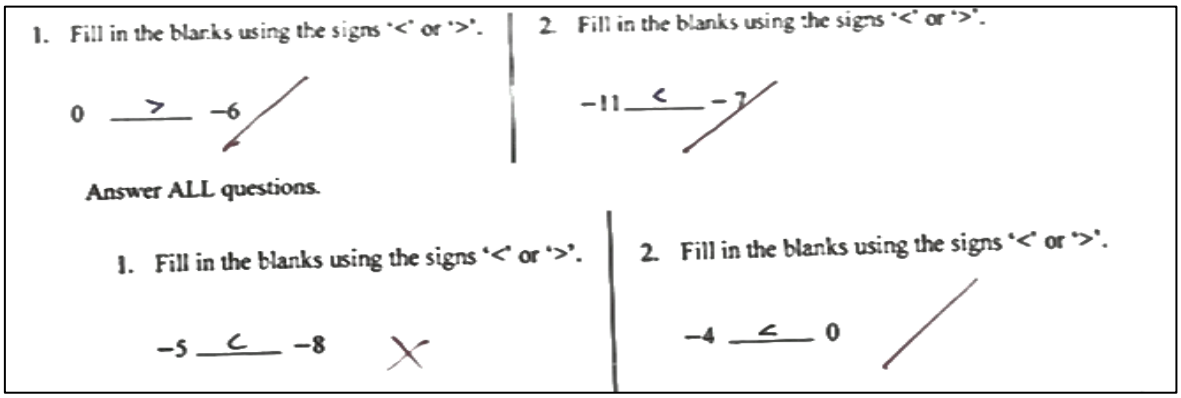

Figure 3. Common errors in questions 1 and 2

In Figure 3, it is observed that participants scored both questions in the pretest but missed one of the questions in the posttest. They make a common error in the posttest by ignoring the negative sign of the negative integers.

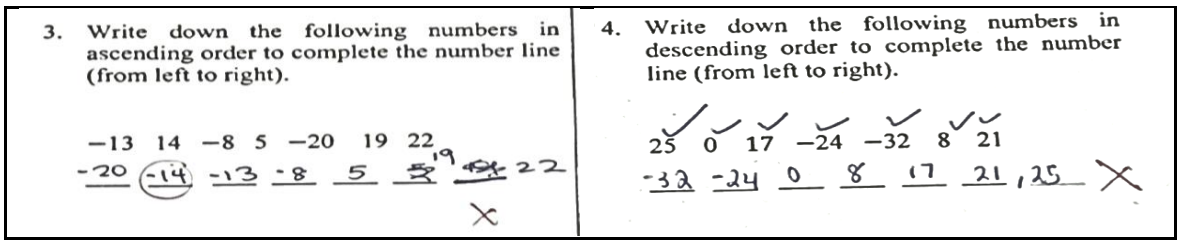

Figure 4. Common errors in questions 3 and 4

In question 3, the participants are confused and read positive integers as negative integers. They ignore the negative sign when arranging the numbers in ascending order and fail to arrange positive numbers first, followed by negative numbers (see Figure 4). In question 4, participants arrange the numbers in ascending rather than descending order. They cannot differentiate the magnitude of positive and negative numbers but mix the numbers up (see Figure 4). According to our observation, they also made the error of misplacing '0' either at the beginning or at the end of the number line. This means that some of them were unable to know the place of zero.

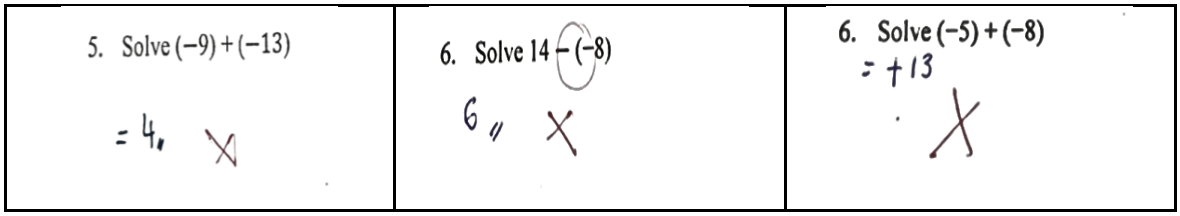

Figure 5. Common errors in questions 5 and 6

The participants ignore the negative sign when performing the operation towards the given integers (see Figure 5). They add two negative integers by disregarding the negative sign after adding. They also fail to differentiate the negative sign as an operation and a symbol. They perform correct calculations of two negative integers but forget to add the negative sign to the final answer (see Figure 5). They still make calculation errors when adding and subtracting directed numbers.

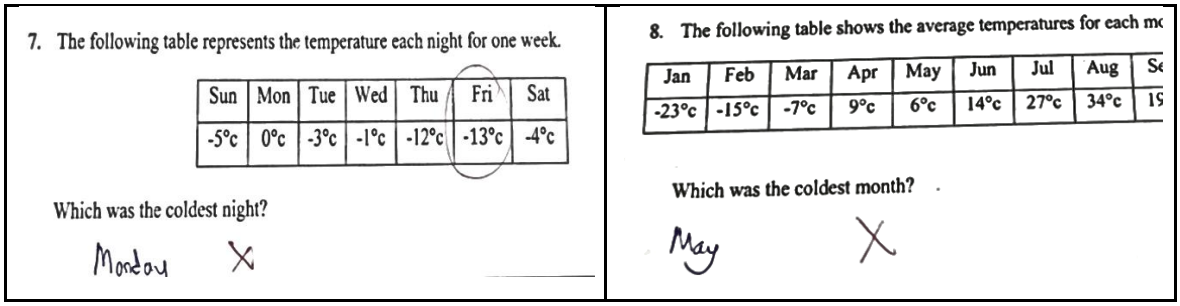

Figure 6. Common errors in questions 7 and 8

The participants think that Monday at 0°C is the coldest night. They have a misconception of assuming that zero is the smallest integer regardless of the negative and positive integers. They similarly answered wrongly by neglecting the negative signs and only focusing on the values. This leads them to choose May with 6°C as the smallest value without considering the negative sign for the negative integers (see Figure 6). This indicates that the participants still had misconceptions despite the significant improvement in performance after the intervention.

3.2. Perceptions of students about the flipped classroom model intervention

Three themes emerged from the interview responses: the usefulness of the flipped classroom, the preferences of the flipped classroom to the face-to-face classroom, and the challenges associated with learning from a flipped classroom model. Generally, the participants had positive perceptions about the flipped classroom model. Despite their positive perceptions, they reported some challenges.

3.2.1. The usefulness of the flipped classroom

Given that traditional teaching and learning may not ensure the best use of instructional time, flipped classroom frees instructional time and provide the room for actvitites that can improve higher order student thinking. Teachers may not waste time to provide instructional information to students when students can access that information from the internet or in textbooks (Matzin et al., 2013; Mazur, 2009). It affords students the opportunities to learn at their peace and take responsibility for their learning (Fulton, 2012). Flipped approaches to teaching and learning help students to learn compared to encountering instructional mateirals in the classrooom. Generally, the students found the flipped classroom through multimedia technology useful. They saw the flipped classroom as helpful in improving their performance in directed numbers as it encouraged collaboration through group work and in-class presentations. This collaboration allowed them to share their knowledge of what they had learned individually and in groups.

S19: I think learning through the video and having a follow-up physical class is very helpful. I understood what directed numbers are, and how to add and subtract such numbers as well.

S5: Engaging in a group work that allowed my peers to share their findings brought up different opinions and thinking among us. In case of any mistakes, my peers were able to correct them, which teaches us the correct way of learning.

S23: … I was able to present in front of my peers, which made me very happy. There was teamwork before arriving at answers. There was knowledge sharing as well.

The students voiced that watching the pre-class video lesson improved their readiness for the face-to-face class. Since flipped classroom comes with flexibility, students are able to control how they learn instructional concepts at home before physical classes. It is worth noting that implementing a flipped classroom tranfers most of the classroom work to students. Going through series of a carefully planned tasks provided by the teacher helps the students to be ready for physical classes.

S23: I watched the video at home. In the class, we had presentations, questions, and answers. I was prepared for the physical class. In temperature, I have now understood that a negative number means too much coldness. A positive number is bigger than a negative number, and zero separates all of them…

3.2.2. Preferences of the flipped classroom to the face-to-face classroom

The participants found the flipped lesson as helpful and convenient to learn directed numbers. Learning through pre-class video at home improved their understanding. At the same time, the face-to-face classroom helped clarified their misconceptions and received further explanations from their teacher. Generally, they preferred to learn through the pre-class video lessons and face-to-face classes.

S5: It is easy to understand directed numbers when you watch the video at home and have the group work in a physical classroom.

S19: I think I will prefer both. But it is always good to learn through the video at home before the actual class.

Flipped classroom is effective as face-to-face learning (Stratton et al., 2020). This suggests that effective use of both instructional approaches in mathematics classrooms have the potential to improve student learning and performance. The latter promotes group work and helps clarify student doubts compared to learning through a pre-class video lesson alone. Students exhibit high level of confidence to perform instructional tasks and positive percpetions when they are exposed to different instructional methods including hybrid, traditional and flipped classrooms (Kaleem et al., 2016). Given this background, it is not surprising that our participants preferred both the flipped classroom and face-to-face instruction. They are able to learn through pre-class video lessons by themselves at home and clarify their doubts during normal classes.

S1: Can we choose both? Because both are helpful for students. The flipped classroom helps us understand the video and learn by ourselves. The traditional classroom helps us to get further explanations from the teacher.

S26: Both…by watching the video, I hear everything and can rewind it severally. In the normal lessons, I write any important information which I make reference to and ask the teacher the questions I want.

3.2.3. Challenges associated with learning from a flipped classroom model

Although the participants found the flipped classroom model helpful in improving their performance in directed numbers and expressed positive perceptions of its use, they reported some challenges. They were faced with limited time for group discussions which affected their preparation for the in-class presentations. Negative attitudes of group members also affected their meeting time. The participants voiced that the flipped classroom where pre-class videos are watched at home limits how they are can ask questions.

S20: I did not have much time to discuss with my group, which affected my understanding and contributions.

S1: There were also different opinions which sometimes disturbed the class.

S29: …I am not able to ask the teacher questions when I learn from the pre-class video at home. I can only ask questions during the face-to-class. This made me to forget most of questions I wanted to ask.

3.3. Discussion

The results of this study indicate that the implementation of a flipped classroom through multimedia technology has the potential to improve students' performance in directed numbers. This is expected because students are exposed to instructional tasks at home, preparing them for face-to-face instruction. The teacher facilitates classroom interaction through group work and activity-based learning. This encourages and motivate students to collaborate and share knowledge. The teacher also clarifies any misconceptions and misunderstandings that students may have. These are the characteristics of a flipped classroom model reported in the literature (Ash, 2012; Lin & Chen, 2016; Say & Yildirim, 2020), which encourages student-centred learning (Jamaludin & Osman, 2014). Therefore, students are expected to improve their performance.

The results of this study indicating that a flipped classroom model has the potential of improving students' performance in directed numbers confirm existing studies that support the efficacy of the flipped model in teaching and learning (Busebaia & John, 2020; Sirakaya & Ozdemir, 2018; Strelan et al., 2020). The use of multimedia and, in particular, video lessons enhance students' performance. Video lessons have the potential to improve students' engagement and, at the same time, provide explanations and help them remember learning content compared to audio or other multimedia (Hew & Lo, 2018). Students have the flexibility to rewind, pause, and skip the video lesson based on their preference, which may positively affect their understanding and performance (Fulton, 2012; Matzin et al., 2013). Given this analysis, this might have helped students enhance their understanding when provided with the pre-class video lesson on directed numbers. This confirms the relevance of multimedia technology such as video lessons in improving students' performance in a flipped classroom model (Botha-Ravyse & Reitsma, 2015; Oliveira, 2018), especially in directed numbers. Therefore, it was not surprising that the students reported that they could access instructional content conveniently when given the pre-class video lesson, which confirmed the literature (Aprianto et al., 2020).

It is also interesting to reiterate that the students used in this present study generally perceived a flipped classroom environment positively. This suggests that the students benefitted from the filipped model. Considering the zeal, participation, motivation, and understanding gained by the students, their positive views were expected (Bofferding, 2014; Oliveira, 2018). However, the students still had some misconceptions and

misunderstandings and made some errors in directed numbers. This reminds us of student difficulty on directed numbers reported in the literature (Bofferding, 2014; Lamb et al., 2012; Vlassis, 2008) and the errors students make, especially on negative integers acknowledged by previous studies (Fuadiah & Suryadi, 2017; Lamb et al., 2012; Levison, 2016). We agree with Oliveira (2018) that a flipped class is not a sufficient condition for improvement in student learning. In this study, most students reported that they had limited time to present and discuss instructional tasks. They were not able to ask questions while studying at home, and were distracted when studying at home. These can contribute to create common errors in delivering their answers. Therefore, it was not surprising that despite the efficacy of the flipped classroom intervention, students still preferred both flipped and traditional face-to-face learning in directed numbers.

Given the improvement that is witnessed in the performance of students after the intervention provided, there are certain pedogicial approaches we undertook that might have contributed to students' performance. We believe that these pedagogical approaches are worth practicing by other mathematics educators. We used WhatsApp as a learning platform during the pretest. Students were pleased and were able to respond to the learning tasks through WhatsApp before the intervention. This suggests that during COVID-19, social media plateforms can be carefully untlised to promote student learning in mathematics. Our intervention was based on edited videos that illustrated series of concrete mathematical actions based on the concepts taught. The students experienced pictorial representations of what they were taught compared to teaching them in abstract terms. Teachers should be able to develop and integrate the technology that enhance student learning to improve their performance in directed numbers. Generally, the intervention involved an activity-based lesson through group work and collaboration, and allowed students to present their findings before addressing any questions they had. We planned the intervention in a such way that there were a lot of activities. This makes us to believe that most of the benefits of flipped classroom model depend on what happens in the classroom compared the instructional tasks students go through at home. Teachers should plan carefully and ensure student-centred teaching and learning to improve performance in directed numbers. These attempts that characterised our flipped classroom through multimedia technology have the possibility to improve the performance of students as we have reported.

4. CONCLUSION

This study examined the effectiveness of a flipped classroom model through multimedia technology in improving students' performance in directed numbers. The results showed that a flipped classroom model could improve students' performance in directed numbers. Generally, the students had positive perceptions of the flipped classroom model. The model improved student readiness, preparation, participation, and motivation in the teaching and learning process. Using a flipped classroom also comes with challenges. Students may lack group work and discussion time, and they may be disctracted by home activities. Therefore, they prefered flipped classroom lessons and traditional face-to-face teaching and learning of directed numbers. Our results imply that during the COVID-19 pandemic, a flipped classroom through multimedia technology, such as video lessons, can be an effective and alternative way of teaching and learning directed numbers in secondary schools. It can encourage student-centred learning and improve students' creative ability, which is vital in teaching and learning mathematics.

This study draws the attention of mathematics teachers and schools to consider a flipped classroom as an alternative way to teach and learn directed numbers and other mathematics concepts. Key stakeholders such as schools and parents may also consider

providing the necessary devices, materials, and environment to make a flipped classroom feasible. This study reminds mathematics educators that students have a great deal of misconception about directed numbers despite the intervention provided. They were confused about where to place "0" among positive and negative intergers, failed to differentiate between a negative sign as a symbol and as an operation, inability to determine the maginitute of positive and negative numbers and ignoring negative signs after calculations. These suggest areas where flipped classroom through multimedia technology can be used to improve the teaching and learning of directed numbers.

This study covered a relatively small sample size to assess the effectiveness of the intervention provided. The effectiveness of our intervention was also confirmed in the teaching and learning of directed numbers. Therefore, generalising our results to other mathematical concepts, subjects, and in different educational contexts should be done with care. Given these limitations, we suggest that future studies consider replicating our study in other school and educational contexts, using a relatively large sample, to arrive at more robust conclusions on our study variables. Future studies may consider extending the efficacy of a flipped classroom model to other mathematical concepts and subject areas across educational contexts. Comparing other multimedia technologies in a flipped classroom to assess their effectiveness in improving students' performance may also be an important focus of research.

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