IEEE Access
Multidisciplinary ⋮ Rapid Review ⋮ Open Access Journal

Received 7 November 2022, accepted 12 December 2022, date of publication 19 December 2022,
date of current version 13 January 2023.

Digital Object Identifier 10.1109/ACCESS.2022.3230860

RESEARCH ARTICLE

The Effectiveness of a Technology-Based Isometrical Transformation Flipped Classroom Learning Strategy in Improving Students' Higher Order Thinking Skills

KALAIARASI NADARAJAN[1], ABDUL HALIM ABDULLAH[1], (Member, IEEE), NAJUA SYUHADA AHMAD ALHASSORA[1], NOR HASNIZA IBRAHIM[1], (Member, IEEE), JOHARI SURIF[1], (Member, IEEE), DAYANA FARZEEHA ALI[1], NORASYKIN MOHD ZAID[1], AND MOHD HILMI HAMZAH[2]

[1]Faculty of Social Sciences and Humanities, School of Education, Universiti Teknologi Malaysia, Johor Bahru 81310, Malaysia
[2]School of Languages, Civilisation and Philosophy, Universiti Utara Malaysia, Sintok 06010, Malaysia

Corresponding author: Abdul Halim Abdullah (p-halim@utm.my)

This work was supported in part by the UTM Fundamental Research under Grant Q.J130000.3813.21H85, and in part by the Ministry of Higher Education Malaysia and Universiti Teknologi Malaysia.

This work involved human subjects or animals in its research. Approval of all ethical and experimental procedures and protocols was granted by the Malaysian Ministry of Education under Reference No. KPM.100/15/2/135(08).

ABSTRACT Isometric Transformation is one of the essential topics in the Malaysian Secondary School Mathematics Curriculum. In general, Malaysia's achievements in Trends in International Mathematics and Science Study (TIMSS) and Program for International Student Assessment (PISA) were found to be less encouraging, especially in the field of Geometry. This fact clearly implies that the mastery of Higher-Order Thinking Skills (HOTS) of Malaysian students is still low, especially in the topic of Isometric Transformation. Therefore, this study was conducted to develop Flipped Classroom Learning Strategy (FCLS) activities and evaluate their effectiveness in increasing Malaysian secondary school students' HOTS in Isometric Transformation. This study was conducted in two stages whereby the first stage involved the development of FCLS activities, while the second stage was run to evaluate the effectiveness of FCLS activities in enhancing students' HOTS for the topic of Isometric Transformation. The development of activities involved three phases. The first phase was the needs analysis phase which involved a preliminary survey towards students' learning difficulties at each level of HOTS in the topic of Isometric Transformation. The second phase was the design and development stage of FCLS activities, involving the learning activities inside and outside the classroom in line with the topic of Isometric Transformation. The last phase was the evaluation phase which involved the content validation and evaluation on the suitability of FCLS activities by 11 experts. Next, the second stage was a quasi-experimental design which involved 131 Form 2 students from two secondary schools in Johor. The study sample was divided into two groups which were the treatment group and the control group. The study was conducted over eight weeks. Mann-Whitney test results showed a significant difference ($p = .000 < .05$) in the overall level and also for all of the four levels of HOTS for both control and treatment groups. The results of this study showed that the teaching and learning process that used FCLS activities successfully created an effective learning situation in improving students' HOTS in the topic of Isometric Transformation. In conclusion, these FCLS activities should be used as guidelines for educators to increase HOTS in mathematics education.

The associate editor coordinating the review of this manuscript and approving it for publication was Laxmisha Rai.

INDEX TERMS Flipped classroom, higher order thinking skills (HOTS), isometric transformation.

I. INTRODUCTION

Education is one of the platforms that can cultivate higher order thinking skills (HOTS) and 21st century learning skills [1]. HOTS is a concept that emphasizes critical thinking skills rather than rote memorization. One of the most popular HOTS taxonomies of learning was introduced by Bloom 1956 which included knowledge, comprehension, application, analysis synthesis and evaluation. However, in 2001, the revised Bloom's Taxonomy was introduced by Anderson and Krathwohl. The top three thinking skills in the Bloom Taxonomy involved critical or higher-order thinking skills. HOTS plays an important role in developing human capital that can compete at the global level [2]. In this regard, many countries such as the United States [3], South Korea [4], [5], Singapore [6] have prioritized HOTS in their education systems including Malaysia. In order to foster and empower HOTS, the Malaysian Ministry of Education has launched the Malaysian Education Blueprint 2013-2025 that has been clearly incorporated in the learning standards for the Primary School Standard Curriculum and the Secondary School Standard Curriculum [7]. The Ministry of Education has adopted Anderson's revised edition of the Bloom Taxonomy hierarchy in the national education system and employed it as one of the important elements in the curriculum framework for all subjects including mathematics. This can help students master all levels of HOTS which refers to the skills of applying, analyzing, evaluating and creating. These skills are greatly emphasized in the Malaysian education system [2].

HOTS is the ability to apply knowledge, skills and values in reasoning and reflecting in order to solve problems, make decisions, innovate and create something [2]. This skill is also emphasized in mathematics subjects. It is important for students to master this skill that enables them to face challenges and take risks in trying new solution methods. However, these objectives will be difficult to achieve if students are unable to master mathematics subjects, especially in terms of solving HOTS problems. This is evident in the performance of Malaysian students in international assessments, such as Trends in International Mathematics and Science Study (TIMSS) and the Program for International Students Assessment (PISA), which show a less than satisfactory level [8]. Meanwhile, the poor performance of secondary school students in public examinations also lends evidence that the mastery of mathematics is still low in which many students are still unable to answer the mathematics questions [9]. This clearly shows that Malaysian students are weak in the mastery of the international and local HOTS assessments. Their performance, unfortunately, does not meet the Ministry of Education's targets. Therefore, efforts to cultivate and improve students' HOTS, especially in mathematics subjects, need to be given due attention.

HOTS in the teaching and learning process is critical in order to meet the demands of the National Philosophy of Education and the country's needs towards achieving the status of a high-income developed country [10]. The revolution in mathematics education is now also focusing on HOTS. However, previous studies show that HOTS among Malaysian students is still low in both international [11], [12] and national assessments [13]. This is evident in the declining pattern in the assessments of TIMSS 1999, TIMSS 2003, TIMSS 2007, PISA 2011 and PISA 2012 [14], [15], [16]. This finding is further reinforced by a needs study report by Consultants Kestrel Education (UK) and 21st Century Schools (USA) which found that the mastery of HOTS among Malaysian teachers and students is still low.

The low mastery of HOTS among students is due to the implementation of teachers' pedagogical practices [17]. In Malaysia, many teachers still use conventional teaching methods [18]. In addition, mathematics teachers are still struggling with good pedagogical practices for teaching HOTS [19], [20]. Teachers are also still confused about the use of specific keywords for the formulation of HOTS questions [8], as supported in [21] in which the authors claim that teachers are still at a moderate level in the application of HOTS since they are unable to plan questions, assignments and activities that require students to develop thinking skills. As a result, students' thinking has to be trained with open questions in order to understand new learning in mathematics [22]. Next, the students' low level of HOTS in mathematics is linked to their lack of knowledge to connect information in their daily life [23], [24], [25]. This includes students' difficulties in solving HOTS questions using a hands-on solution strategy, which is due to their poor grasp of basic mathematics knowledge [26], [27]. This problem occurs since students tend to memorize formulas without understanding concepts, theorems and formulas in mathematics. They also provide correct answers without using their existing knowledge and experience [28].

It can be concluded that Malaysian students are still at a low level of mastery of HOTS in mathematics, which is below the level expected by the Ministry of Education. Therefore, many studies have been conducted that aim to improve students' HOTS [22], [29]. However, these studies neglect the topic of Isometric Transformation. Therefore, the current study was conducted by considering the use of a flipped classroom learning strategy (FCLS) in order to increase students' HOTS for the topic of Isometric Transformation.

II. DIFFICULTY IN LEARNING ISOMETRIC TRANSFORMATIONS

Students' mastery on the concept of transformation geometry is important as it helps them in enhancing the analyzing and synthesizing skills as well as the problem-solving skills [30]. According to [31], learning geometry can provide opportunities for the students to develop their spatial visualization skills. In addition, learning geometry also can enhance reasoning and critical thinking skills among the students [32]. Thus, by understanding and mastering the concept of transformation geometry, the students can indirectly understand the other mathematical concepts.

Many researchers have focused on Isometric Transformation which is the eleventh topic based on the Form Two Mathematics Curriculum and Assessment Standard Document. This document prioritizes transformation, translation, reflection, rotation, isometry, congruence and rotational symmetry [2]. Isometric transformation is a topic that demands attention from relevant parties involved in the mathematics curriculum [33]. However, the 2015 TIMSS study report showed that only 30% of Form Two students in Malaysia were able to answer the symmetry and reflection concept questions correctly. This percentage is relatively low compared to the international average, which is 50.9%. This result proves that Malaysian students have not mastered the concept of symmetry and reflection. They are also unable to relate symmetry to everyday life [34]. Moreover, [35] support the above statement by stating that there is a substantial difference between students in Malaysia and those in Singapore in terms of their achievements in the geometric cognitive domain; Malaysian students are rarely exposed to open-ended questions as well as non-routine and hands-on exercises in the topic of Isometric Transformation [34].

Students' difficulties in answering HOTS questions for Isometric Transformation can be linked to their inability in obtaining mathematical information [36], [37]. This situation is due to difficult sub-topics that involve the exploration of translation, reflection, rotation, isometry, congruence, and rotational symmetry [38], [39]. It was found in previous studies that students are unsure about the exact terms for translation and rotation, including the drawing images of rotation that are inaccurate [40], [41], [42].

Students, therefore, need to apply HOTS in order to avoid misconceptions in the topic of Isometric Transformation [43]. Furthermore, students also experience problems especially when making generalizations about the transformation patterns associated with their daily life [44]. Although teachers guide students to transfer their knowledge to non-routine and real-life situations, students still face difficulties in relating the topics to their daily life situations [38]. This shows that it is critical to transfer the topic of Isometric Transformation into students' daily life so that they can understand the topic in greater depth [45]. Passive students usually show poor thinking skills during teaching and learning since they are reluctant to provide ideas during discussion activities and submissive to the suggestions from their group mates [46].

In conclusion, all the studies above show the difficulties experienced by students in the topic of Isometric Transformation [41], [47], [48]. One of the learning strategies that can be used to make it easier for students to understand this topic is the integration of technology and communication, which is through a flipped classroom by [49]. Through a technology-based flipped classroom, students can understand related topics in depth and relate such topics to their daily life.

III. FLIPPED CLASSROOM LEARNING STRATEGY (FCLS) IN MATHEMATICS CLASSROOM

In Malaysia, a flipped classroom is one of the pedagogical strategies that has been emphasized by the Ministry of Education in secondary schools [14]. Four pillars behind the flip learning in Malaysia are flexible environments, learning cultures, intentional contents, and professional educators. It was indicated in one recent study that the flexibility and versatility features of a flipped classroom made it widely diffused in the Malaysian classroom context [50]. According to [51], a flipped classroom method provides space and opportunities for students to learn at their own pace and encourages them for active learning.

Past studies show that the Flipped Classroom Learning Strategy (FCLS) has great potential to be implemented in mathematics education [52]. Among the advantages of this FCLS is that students can plan and evaluate the study period correctly [53]. Students can also plan their learning activity time by interacting with their peers outside and inside the classroom. This makes it easier for them to interact with their teachers if there is ambiguity about the concept [54]. Teachers will provide feedback so that students can address potential problems raised in the classroom. In this way, teachers can maximise their time in the classroom. Indirectly, students will build a collaborative network to help them improve their academic performance [55].

Through FCLS, students can also answer questions related to the topic and receive appropriate feedback in the form of quizzes submitted online before FCLS activities [56]. Students can also directly ask questions so that teachers are able to provide solutions. Therefore, FCLS based on information and communication technology will help teachers to be more prepared to face various questions and problems from their students [57].

According to [58], this learning strategy will enable students to apply HOTS and master mathematics concepts in the classroom. After learning mathematics using this FCLS, students will be more confident to solve mathematics HOTS questions [59]. However, there is limited research that examines the implementation of FCLS in mathematics including activities conducted before, during and after the teaching and learning process. This limitation is evident either internationally [60] or locally [61], [62], [63]. The initial study conducted by Mukherjee and Pillai [63] in Malaysia focused only on the implementation of FCLS in the higher education setting. The study shows that FCLS has potential benefits in knowledge development, collaborative learning and time-saving in the classroom [64]. However, the study does not detail out the level of implementation at the secondary school level. Subsequently, a quasi-experimental study was conducted by [65]; she suggested that the implementation of FCLS could be extended to regular high school students in order to see the impacts and constraints from other contexts. As a result, other researchers started to consider the gap in previous studies by developing FCLS activities for daily secondary school students and by looking at the impact of these activities in terms of HOTS' mastery

IV. THE POTENTIAL OF A FLIPPED CLASSROOM LEARNING STRATEGY (FCLS) TO IMPROVE STUDENTS' HIGHER ORDER THINKING SKILLS (HOTS) IN MATHEMATICS

A flipped classroom gives students the opportunity to have their own learning space and learning pace. In the conventional method, students may not be able to follow the speed of teachers' delivery which can reduce the amount of information delivered to students [66]. As a flipped classroom is parallel to the student-centered learning paradigm in which students are responsible for their learning process [67], students can manage and regulate their learning and thinking in a more effective manner. In addition, considering the fact that the high-level thinking process requires a lot of cognitive investments, the flexibility features of a flipped classroom can reduce the cognitive load faced by students.

Previous studies have shown that the activities using the flipped classroom learning strategy (FCLS) in teaching mathematics at secondary schools are still underexplored. According to [68], teachers need to give more attention to activities for FCLS. It turns out that most researchers do not detail out how to implement activities for FCLS in teaching and learning [69], leading to difficulties among teachers in implementing FCLS [70]. Therefore, this study aims to develop activities for FCLS as teaching aids that can be used by teachers in teaching and learning so that it is easier for students to understand and answer HOTS questions on the topic of Isometric Transformation. The FCLS activities were developed with complete implementation guidelines that aimed at helping to reduce problems and constraints among teachers. The theory of Social Constructivism by [71] was chosen as the underlying principle for the development of activities for FCLS. This theory of Social Constructivism was emphasized in all three phases, including those activities that focused on the students' HOTS, as found in the flipped classroom model by [72], which was also adapted in the objectives of the current study.

Each activity in FCLS was developed by the researchers according to the hierarchy of learning in the topic of Isometric Transformation as specified in the Standard Document of Curriculum and Assessment for Form Two Mathematics Curriculum [2]. The activities for FCLS were divided into several sub-headings and built sequentially so that these activities would be applied effectively inside and outside the classroom. The development of such activities would help teachers implement FCLS in the teaching and learning of mathematics in secondary schools in order to increase students' HOTS through the three phases of implementation.

In the first phase, which was the exploratory phase, the activities for FCLS would increase students' motivation by watching videos and additional reference materials to learn mathematics and stimulate the mastery of HOTS [59], [73]. The second phase, which was the phase of application, involved learning outside and inside the classroom in which the teachers could relate advanced knowledge about the concepts by answering various forms of mathematics HOTS questions [74]. Through FCLS activities, teachers could guide students in completing comprehensive exercises that involved the skills of applying, analyzing, evaluating and creating for each sub-topic in Isometric Transformation [75]. The variety of activities with group members would increase students' motivation and create a comfort zone for them [76].

The third phase was the reflection phase which required students to conduct self-reflection for the improvement of individual learning. With the help of FCLS activities, teachers could also improve the teaching and learning process [77], [78]. Indirectly, teachers could improve students' HOTS [22], [79]. This is in line with FCLS which has the potential to increase students' understanding, encourage their critical and creative thinking skills, and increase their achievement and motivation [59].

V. RESEARCH OBJECTIVES

1. To develop activities for the technology-based flipped classroom learning strategy (FCLS) in the topic of Form Two Isometric Transformation.
2. To study the effectiveness of the implementation of activities for the technology-based flipped classroom learning strategy (FCLS) on students' Higher Order Thinking Skills (HOTS) in the topic of Isometric Transformation.

VI. RESEARCH METHODOLOGY

The design of this study was divided into two stages, namely (1) the design and development stage and (2) the effectiveness testing stage. The first stage focused on the development of products and hardware, i.e., the intended product for FCLS [80], [81]. The development of activities for FCLS employed the design principles of [82] model as a guide in building interactive and systematic teaching and learning activities. This model was chosen in the development of activities for FCLS in order to test and verify the theory in practice [83].

In the design and development stage, there were 11 experts involved in this study. In order to ensure that the activities developed were appropriate, two senior Mathematics lecturers, two excellent teachers and a Malaysian Secondary School Standard Curriculum Lead Trainer for Mathematics provided comments and feedback on the draft activities developed. The expert evaluation of the instruments and draft activities aimed to obtain an evaluation of the content validity of the items. Meanwhile, a language expert was also appointed to assess whether the language used was easy to understand by the students. After the confirmation of the draft activities for FCLS, the improvement process was carried out according to the comments and feedback from the experts.

Next, the improved draft was evaluated by five expert teachers. This step aimed to obtain an assessment of the content validity of the items as well as language appropriateness. After the confirmation of the draft activities based

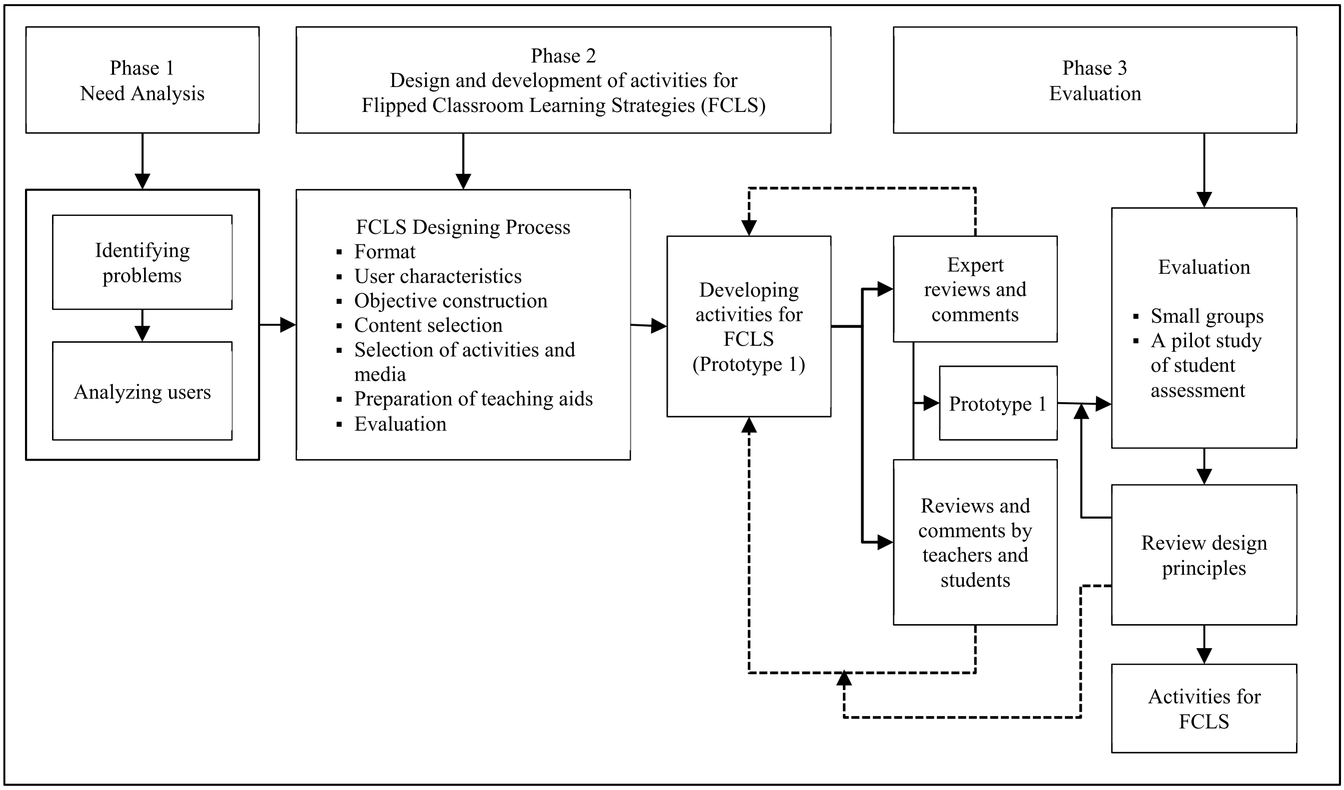


FIGURE 1. Process development for FCLS activities.

on the comments and feedback from the expert teachers, the improved draft was given to five Form Two students to be evaluated from the students' point of view. Based on the views and suggestions from the students, modifications were made to some sentence structures and terms in the research questionnaire.

In the context of this study, this model was compatible with the Social Constructivism Theory. This theory was applied in FCLS through teaching and learning activities that were expected to contribute to the cognitive development of students in an interactive and dynamic learning environment. In the activity development process, the researchers applied the activity construction steps suggested by [82] through three main phases, as shown in Fig. 1.

Fig. 2 lists down activities in the three phases of learning based on the characteristics of the Social Constructivism Theory implemented in FCLS [72]. In developing the activities for FCLS, the researchers prioritized the three phases of learning, namely the exploration phase before learning, the application phase and strengthening of concepts during teaching and learning, and the reflection phase after teaching and learning [84]. Among the activities in the first phase were out-of-class learning that encouraged students' inquiry by watching videos and commenting, exploring the topic on their own, preparing with additional references, and answering online quiz questions [59]. Sending video links via WhatsApp allowed students to conduct investigations and find answers to problems given at the beginning of learning [85], [86]. This phase aimed to improve the nature of discovery among students. Students also needed to comment on videos in virtual chat rooms or forums so that they could communicate with other students or teachers about a specific concept. The purpose of this room was to allow students to exchange opinions, share knowledge and reflect after or during the learning mode [87]. Teachers could also ask questions that could stimulate students through online quizzes [88]. The second phase was particularly conducted to observe student-centered teaching and learning activities. Teachers could initiate teaching and learning in the classroom by making connections between topics presented in video links or quizzes. Students' views and answers could help teachers detect difficulties in the topic and avoid students' misconceptions [89]. Group learning activities could give students the opportunity to improve their weaknesses. Besides, training in the form of HOTS could give students the opportunity to master learning more deeply and to draw conclusions. This phase aimed to guide students to think outside the box in order to solve problems, express ideas and information confidently.

Finally, the reflection phase was conducted after class in which students provided feedback about the day's teaching and learning. Students also read additional materials on the topics learned, followed by hands-on activities such as projects so that knowledge could be applied in real situations. At the stage of selecting activities, media and teaching aids,

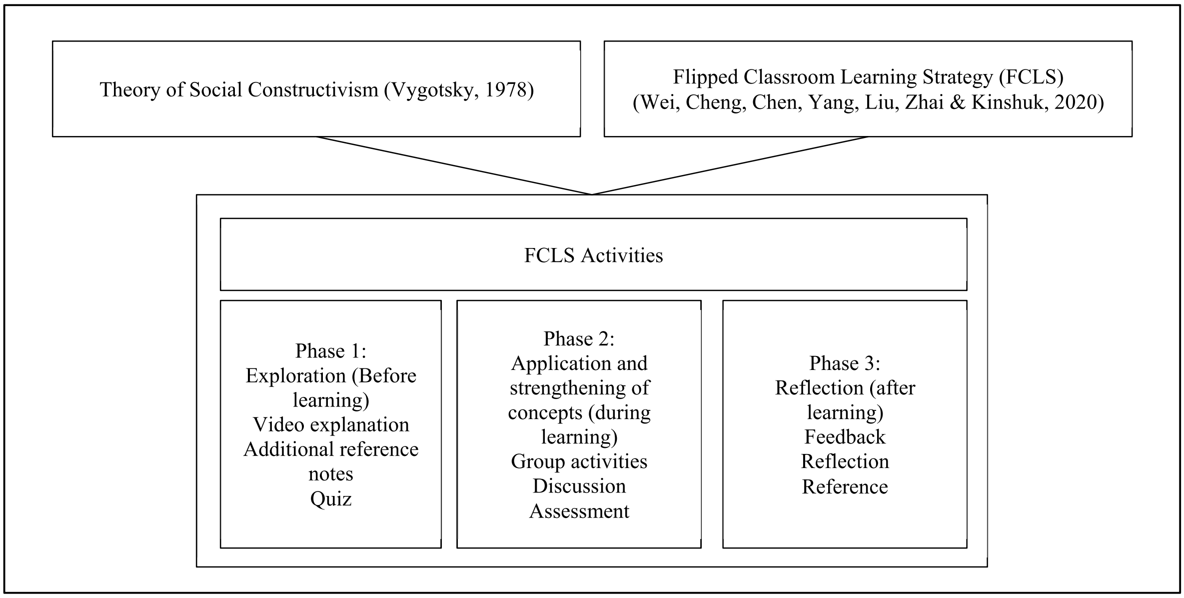


FIGURE 2. FCLS and three phases of learning.

the researchers arranged them based on [90], as shown in Table 1.

A. EFFECTIVENESS TESTING

The second stage was to test the effectiveness of activities for the FCLS that were built in improving students' HOTS in the topic of Isometric Transformation. A quasi-experimental design was used in this stage involving a pre-post Isometric Transformation HOTS test [91], [92]. A quasi-experimental design was suitable as the present study aimed to test the effectiveness of students' HOTS in the topic of Isometric Transformation. Moreover, [93] also support this design because of its strength. In this study, a quasi-experimental design was used for the treatment group who was involved in FCLS activities. Meanwhile, the control group underwent conventional learning with the help of textbooks, power point presentations, workbooks and worksheets. All learning activities for the control group took place in the classroom environment. This coincides in [94] in which the author states that the treatment group should receive a new treatment while the control group is maintained in the usual form. The two groups were given a pre-test and a post-test before and after the study was conducted, as shown in Table 2.

Table 2 shows a quasi-experimental design that uses a non-equivalent group's pre-post-test design. This design was chosen because existing groups were used so as not to disturb the school's natural environment. The sample was equivalent in several aspects such as age, background, academic qualifications and existing knowledge [95]. The researchers selected a treatment group consisting of Form Two students at a secondary school; this group used FCLS activities in the topic of Isometric Transformation (X1). Meanwhile, the control group consisted of Form Two students at another secondary school; this group received conventional learning (X2). The treatment and control groups were chosen from different schools to avoid the threat of internal validity and subsequent invalidity in the results of the study.

In the first week, a pre-HOTS Isometric Transformation test was given to the treatment group (X1) and also the control group (X2). After the pre-test was conducted, the treatment group (X1) followed the activities for FCLS in the learning session starting in the second week for eight weeks. Meanwhile, the control group (X2) followed conventional learning for eight weeks. In the following week, the treatment group (X1) and the control group (X2) were given a post-HOTS Isometric Transformation test. The time period for the post-test was considered appropriate. According to [96], the appropriate period for conducting a post-test is within a period of one month, six months or a year after a pre-test. This is recommended in order to minimize the internal validity of the study caused by the subjects' maturity factor. However, this quasi-experimental design was still exposed to some threats of validity and reliability [96]. To ensure that the findings of the study were due to treatment factors only, the researchers made efforts to control the threats to the validity of internal and external data before conducting the study [97].

B. ISOMETRIC TRANSFORMATION HOTS TEST

The Isometric Transformation HOTS test was conducted to identify the effectiveness of FCLS activities on HOTS' mastery in the topic of Isometric Transformation. The construction process of the HOTS mathematics items involved four stages: (1) preparing the Test Specification Table, (2) building the items in each construct, (3) sending the constructed items to a discussion session with the experienced teachers, and (4) sending the constructed instrument to experts for

TABLE 1. FCLS sessions and activities for the isometric transformation topic.

Session/ Title	Activities	Phase/ Duration	Self activities' attachments
Session 1: Introduction to HOTS in mathematics	Introduction to FCLS & HOTS in mathematics	Exploration phase (10 minutes)	a. FCLS introduction 1 b. Watch videos uploaded on Google Classroom. c. Session 1 feedback exercise - I-think questions. d. Students are required to answer questions and upload in Google Classroom. e. Students read the additional reference -Parental monitoring.
		Application and strengthening of concepts phase (90 minutes)	a. The teacher starts the learning by linking the videos uploaded in Google Classroom and by discussing the feedback. b. Learning in groups: Students conduct activities in groups in which a leader will distribute questions to friends. c. They discuss the answers and present the answers in groups – 21st century pedagogy d. Feedback / evaluation by the teacher e. Giving appreciation.
		Reflection phase (10 minutes)	a. Teachers give feedback individually. b. Students receive reward points based on set criteria. c. Teachers introduce new sub-topics in Google Classroom.
Session 2: Transformation	FCLS & HOTS 2: Transformation	Exploration phase (10 minutes)	a. Watch videos uploaded in Google Classroom. b. Session 2 - Quiz feedback exercise c. Students are required to upload scores in Google Classroom. d. Students read additional references - Parental monitoring.
		Application and strengthening of concepts phase (90 minutes)	a. Teacher starts teaching and learning by linking uploaded videos and quiz questions to avoid students' misconceptions. b. Learning in groups: Students conduct activities in groups in which a leader will distribute HOTS questions to friends. c. They discuss the answers and present the answers in groups - 21st century pedagogy d. Feedback / evaluation by the teacher e. Giving appreciation.
		Reflection phase (10 minutes)	a. Teachers give feedback individually. b. Students write reflections on class learning. c. Read additional references and watch videos as reinforcement activities. d. Teachers introduce new sub-topics in the Google platform.
Session 3: Translation	FCLS & HOTS 3: Translation	Exploration phase (10 minutes)	a. Students are required to play digital or non-digital DAM games and upload pictures in Google Classroom. b. Online training. c. Students read additional references -Parental monitoring.
		Application and strengthening of concepts phase (90 minutes)	a. The teacher starts the learning by linking the DAM game and quiz questions to avoid students' misconceptions. b. Learning in groups: Students conduct activities in groups in which a leader will distribute HOTS questions to friends. c. They discuss the answers and present the answers in groups – 21st century pedagogy d. Feedback / evaluation by the teacher e. Giving appreciation.
		Reflection phase (10 minutes)	a. Teachers give feedback individually. b. Students reflect on class learning. c. Students paste colored stickers based on the criteria for reflection on class learning. d. Read additional references and watch videos as reinforcement activities.

TABLE 2. Quasi-experimental study design.

Group	Pre-test	Intervention	Post-test
Treatment	O_1	X_1	O_2
Control		X_2	

Legend:
X_1 = Learning using FCLS activities
X_2 = Conventional learning
O_1= Pre-Test
O_2= Post-Test

validation. In the first stage, the researchers prepared a Test Specification Table based on the Form Two Mathematics Curriculum and Assessment Standard Document for the Isometric Transformation topic. This was to ensure that the test included items that measured various cognitive domains of students [98]. Next, the researchers also studied the existing HOTS Isometric Transformation items in the literature. The purpose was to examine the constructs and items that were previously built by other researchers so that they could be modified according to the context of the current study. Therefore, in the second stage, the researchers adapted some appropriate items from the HEBAT Module (Life, Exploration, Higher Level Thinking) for Mathematics Form Two published by the Curriculum Development Division (CDD), MOE in 2016 [2].

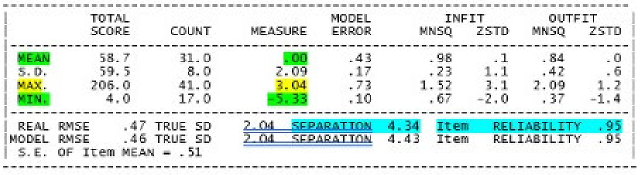
Next, the third stage was a discussion session with experienced teachers to obtain information, ideas and improvements for the construction of HOTS items. This was to further strengthen the items chosen for the Isometric Transformation HOTS test. The researchers also made refinements according to the recommendations given by the experienced teachers. This Isometric Transformation HOTS test consisted of a pre- and post-test. A pre-test is carried out on a sample before they receive treatment [91]. In this study, a pre-test was conducted before the Form Two students underwent activities for FCLS in the topic of Isometric Transformation. The aim was to detect and determine students' HOTS in completing the Isometric Transformation items before the learning took place. The post-test, on the other hand, is a test conducted on samples receiving treatment to measure the characteristics desired in the experiment [99]. In this study, the post-test was given after the teacher used activities for FCLS or conventional learning strategies for two months. This post-test was conducted with the aim of detecting and determining the student's mastery of HOTS in completing Isometric Transformation items after following activities for FCLS or conventional learning strategies. Both of these tests contained the same content, namely four subjective items that were higher level in solving problems for the Isometric Transformation topic. The Isometric Transformation pre- and post-tests are equivalent sets of tests. According to [100], pre-test and post-test questions are supposed to be equivalent, not the same. This is because experimental research that uses the same achievement test can pose a threat to the validity of the study. The fourth stage was the delivery of the instrument to experts for validation.

1) RELIABILITY AND ITEM ISOLATION

In order to determine the reliability of the items in the Isometric Transformation HOTS test, a statistical analysis with the Rasch measurement model was used to obtain the Cronbach-alpha reliability value. Based on the analysis, it was found that the Cronbach-alpha reliability value for the construct of applying and analyzing was 1.00. The evaluating construct gave a reliability value of 0.86, while the creating construct gave a reliability value of 0.82. The analysis of the instrument as a whole for the 22 items gave a Cronbach-alpha reliability value equal to 0.81. This shows that all constructs had a high reliability value that was above 0.80, i.e., the constructs were in accordance with the determined sample. According to [101], a Cronbach-alpha value above 0.80 is an acceptable range for research instruments in research.

In the analysis using the Rasch Model, the reliability can also be reported based on the separation of items and respondents, as shown in Table 3.

TABLE 3. Reliability and item separation values for the instrument.



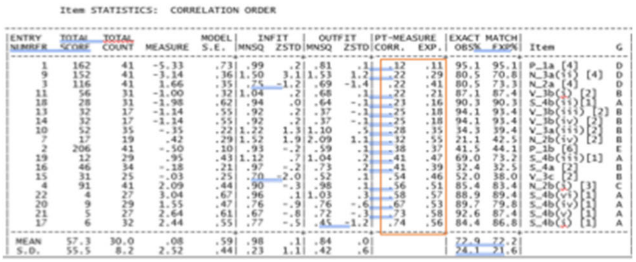
```
-----------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT         OUTFIT       |
|          SCORE      COUNT     MEASURE   ERROR      MNSQ   ZSTD   MNSQ   ZSTD    |
|---------------------------------------------------------------------------------|
| MEAN      58.7       31.0        .00     .43        .98     .1    .84     .0    |
| S.D.      59.5        8.0       2.09     .17        .23    1.1    .42     .6    |
| MAX.     206.0       41.0       3.04     .73       1.52    3.1   2.09    1.2    |
| MIN.       4.0       17.0      -5.33     .10        .67   -2.0    .37   -1.4    |
|---------------------------------------------------------------------------------|
| REAL RMSE     .47 TRUE SD     2.04  SEPARATION  4.34  Item   RELIABILITY  .95   |
|MODEL RMSE     .46 TRUE SD     2.04  SEPARATION  4.43  Item   RELIABILITY  .95   |
| S.E. OF Item MEAN = .51                                                         |
-----------------------------------------------------------------------------------
```

Table 3 shows the item reliability values for the 22 items in the Isometric Transformation HOTS test. The reliability value of the item (item reliability) was high (0.95). These results clearly prove that the reliability value of the item was effective with a high level of consistency as it approached the value of 1.0. The expected repetition of this item was also high and could be extended to other groups of students. It is most likely that this test could reproduce the hierarchy of the items when the variables were measured [102]. Meanwhile, the item separation value was 4.34 [103], lending evidence that the items could be grouped into four difficulty levels of HOTS.

2) PTMEA CORR VALUE TO DETECT MEASURING CURRENT (POLARITY) ITEM

Next, this study also took into account the polarity value that indicates whether the construct should be measured with the PTMEA CORR value. The PTMEA CORR values of the Isometric Transformation HOTS test are shown in Table 4 (between 0.12 to 0.74). According to [102] if the PTMEA CORR value is positive, the item measures the construct that is supposed to be measured. On the other hand, if the PTMEA CORR value is negative (-), the item does not measure the construct that is supposed to be measured, i.e., the item has to be repaired or dropped. Since the PTMEA CORR value is positive, the 22 items can measure the construct to be measured, move in the same direction as the construct, and do not contradict the construct to be measured.

TABLE 4. Polarity value (point measurement correlation) for all items.

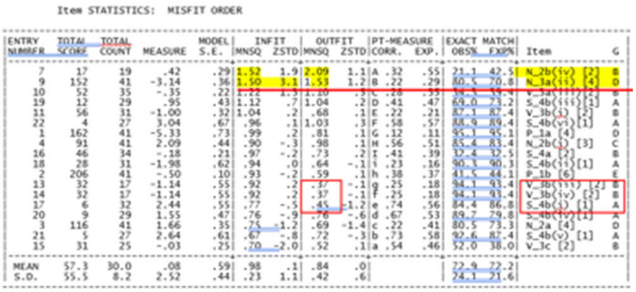


```
Item STATISTICS:  CORRELATION ORDER

-------------------------------------------------------------------------------------------------------
|ENTRY   TOTAL  TOTAL           MODEL|   INFIT  |  OUTFIT  |PT-MEASURE |EXACT MATCH|                  |
|NUMBER  SCORE  COUNT  MEASURE  S.E. |MNSQ  ZSTD|MNSQ  ZSTD|CORR.  EXP.| OBS%  EXP%| Item           G |
|------------------------------------+----------+----------+-----------+-----------+------------------|
|     1    162     41    -5.33   .73| .99    .2| .81    .1|  .12   .11| 95.1  95.1| P_1a [4]       D |
|     9    152     41    -3.14   .36|1.50   3.1|1.53   1.2|  .22   .29| 80.5  70.8| N_3a(ii) [4]   D |
|     3    116     41     1.66   .35| .75  -1.2| .69  -1.4|  .22   .41| 80.5  73.3| N_2a [4]       D |
|    11     56     31    -1.00   .32|1.04    .2| .68    .1|  .22   .21| 87.1  87.4| V_3b(i) [2]    B |
|    18     28     31    -1.98   .62| .94    .0| .64   -.1|  .23   .16| 90.3  90.3| S_4b(ii)[1]    A |
|    13     32     17    -1.14   .55| .92    .2| .37   -.1|  .25   .18| 94.1  93.4| V_3b(iii) [2]  B |
|    14     32     17    -1.14   .55| .92    .2| .37   -.1|  .25   .18| 94.1  93.4| V_3b(iv) [2]   B |
|    10     52     35     -.35   .22|1.22   1.3|1.10    .5|  .28   .35| 34.3  39.4| V_3a(iii)[2]   B |
|     7     17     19      .42   .29|1.52   1.9|2.09   1.1|  .32   .55| 21.1  42.5| N_2b(iv) [2]   B |
|     2    206     41     -.50   .10| .93   -.2| .59    .1|  .38   .37| 41.5  44.1| P_1b [6]       E |
|    19     12     29      .95   .43|1.12    .7|1.04    .2|  .41   .47| 69.0  73.2| S_4b(iii)[1]   A |
|    16     46     34     -.18   .21| .97   -.2| .73    .2|  .41   .39| 32.4  32.5| S_4a [2]       B |
|    15     31     25     -.03   .25| .70  -2.0| .52    .1|  .54   .46| 52.0  38.0| V_3c [2]       B |
|     4     91     41     2.09   .44| .90   -.3| .98    .1|  .56   .51| 85.4  83.4| N_2b(i) [3]    C |
|    22      4     27     3.04   .67| .96    .1|1.03    .3|  .58   .57| 88.9  89.4| S_4b(vi)[1]    A |
|    20      9     29     1.55   .47| .76   -.9| .76   -.6|  .67   .53| 89.7  79.8| S_4b(iv)[1]    A |
|    21      5     27     2.64   .61| .67   -.8| .72   -.3|  .73   .58| 92.6  87.4| S_4b(v) [1]    A |
|    17      6     32     2.44   .55| .77   -.5| .45  -1.2|  .74   .56| 84.4  86.8| S_4b(i) [1]    A |
|------------------------------------+----------+----------+-----------+-----------+------------------|
| MEAN    57.3   30.0      .08   .59| .98    .1| .84    .0|           | 72.9  72.2|                  |
| S.D.    55.5    8.2     2.52   .44| .23   1.1| .42    .6|           | 24.1  21.6|                  |
-------------------------------------------------------------------------------------------------------
```

3) ITEM FIT

Item fit in measuring can be seen through the outfit Mean Square (MNSQ) and infit MNSQ values. Outfit values help detect any outlier or misfit items. Meanwhile, Infit means a match that matches the response pattern to the targeted items and respondents. MNSQ outfit does not cause significant problems in measurement and it is easier to overcome compared to MNSQ infit. Therefore, the researchers checked the MNSQ Outfit to determine the appropriateness of the items that measured a construct. The suggested MNSQ range for polytomous data is 0.5 to 1.5 [102], [104]. Outfit MNSQ values higher than 1.5 are items that are not homogeneous with other items in a measurement scale. Whereas, Outfit MNSQ values that are lower than 0.5 indicate the overlap of constructs with other items. A MNSQ that is out of the MNSQ range will usually show a high z-std value and exceed the accepted range of −2.0 to +2.0. If the MNSQ outfit and infit values are accepted, the Z-std value can be ignored [105]. Table 5 shows the appropriateness of items based on MNSQ values.

TABLE 5. Item fit (item fit) based on MNSQ values.



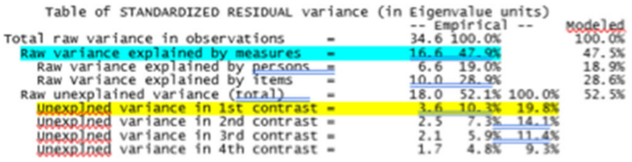
```
Item STATISTICS:  MISFIT ORDER

-------------------------------------------------------------------------------------------------
|ENTRY   TOTAL  TOTAL           MODEL|   INFIT  |  OUTFIT  |PT-MEASURE |EXACT MATCH|            |
|NUMBER  SCORE  COUNT  MEASURE  S.E. |MNSQ  ZSTD|MNSQ  ZSTD|CORR.  EXP.| OBS%  EXP%| Item      G|
|------------------------------------+----------+----------+-----------+-----------+------------|
|     7     17     19      .42    .29|1.52   1.9|2.09   1.1|A .32   .55| 21.1  42.5| N_2b(iv) [2] B|
|     9    152     41    -3.14    .36|1.50   3.1|1.53   1.2|B .22   .29| 80.5  70.8| N_3a(ii) [4] D|
|    10     52     35     -.35    .22|1.22   1.3|1.10    .5|C .28   .55| 54.5  55.4| V_3a(iii)[2] B|
|    19     12     29      .95    .43|1.12    .7|1.04    .2|D .41   .47| 69.0  73.2| S_4b(iii)[1] A|
|    11     56     31    -1.00    .32|1.04    .2| .68    .1|E .22   .21| 87.1  87.4| V_3b(i) [2]  B|
|    22      4     27     3.04    .67| .96    .1|1.03    .3|F .58   .57| 88.9  89.4| S_4b(vi)[1]  A|
|     1    162     41    -5.33    .73| .99    .2| .81    .1|G .12   .11| 95.1  95.1| P_1a [4]     D|
|     4     91     41     2.09    .44| .90   -.3| .98    .1|H .56   .51| 85.4  83.4| N_2b(i) [3]  C|
|    16     46     34     -.18    .21| .97   -.2| .73    .2|I .41   .39| 32.4  32.5| S_4a [2]     B|
|    18     28     31    -1.98    .62| .94    .0| .64   -.1|i .23   .16| 90.3  90.3| S_4b(ii)[1]  A|
|     2    206     41     -.50    .10| .93   -.2| .59    .1|h .38   .37| 41.5  44.1| P_1b [6]     E|
|    13     32     17    -1.14    .55| .92    .2| .37   -.1|g .25   .18| 94.1  93.4| V_3b(iii) [2] B|
|    14     32     17    -1.14    .55| .92    .2| .37   -.1|f .25   .18| 94.1  93.4| V_3b(iv) [2] B|
|    17      6     32     2.44    .55| .77   -.5| .45  -1.2|e .74   .56| 84.4  86.8| S_4b(i) [1]  A|
|    20      9     29     1.55    .47| .76   -.9| .76   -.6|d .67   .53| 89.7  79.8| S_4b(iv)[1]  A|
|     3    116     41     1.66    .35| .75  -1.2| .69  -1.4|c .22   .41| 80.5  73.3| N_2a [4]     D|
|    21      5     27     2.64    .61| .67   -.8| .72   -.3|b .73   .58| 92.6  87.4| S_4b(v) [1]  A|
|    15     31     25     -.03    .25| .70  -2.0| .52    .1|a .54   .46| 52.0  38.0| V_3c [2]     B|
|------------------------------------+----------+----------+-----------+-----------+------------|
| MEAN    57.3   30.0      .08    .59| .98    .1| .84    .0|           | 72.9  72.2|            |
| S.D.    55.5    8.2     2.52    .44| .23   1.1| .42    .6|           | 24.1  21.6|            |
-------------------------------------------------------------------------------------------------
```

Based on Table 5, there are 5 items that are identified as being within the unacceptable range, according to the Rasch measurement model, which is item 2(b)(iv) (MNSQ outfit value is 2.09 from the construct analysis). As for the three items from the construct of evaluating, the MNSQ outfit values are as follows: (1) item 3a(ii) = 1.53, (2) item 3b(iii) = 0.37, and (3) item 3b(iv) = 0.37. For the construct of creating, only one item is not in the range, which is item 4(i) (MNSQ outfit value = 0.45). All of these five items are suggested to be refined based on the needs of the researchers and experts' views.

4) UNIDIMENSIONALITY

Further, the researchers used the Rasch model to examine the unidimensional nature of an item being in one direction only [102]. A unidimensional or non-unidimensional construct is examined using a principal component analysis (PCA) [106]. Linacre [107] states that the minimum variance value must exceed 40% to ensure unidimensionality. Table 6 shows the results of the PCA analysis. It can be observed that the PCA value is 47.9%. This result meets the requirements of Linacre [107] and shows that all of these items are multidimensional (items that measure a wide range of dimensions). Meanwhile, the level of the measured item interference or unexplained variance contrast one (unexplained variance 1st contrast) is 10.3%; this value is well controlled and categorized as moderate [108].

TABLE 6. Unidimensionality.



```
      Table of STANDARDIZED RESIDUAL variance (in Eigenvalue units)
                                               -- Empirical --    Modeled
Total raw variance in observations      =      34.6 100.0%         100.0%
  Raw variance explained by measures    =      16.6  47.9%          47.5%
    Raw variance explained by persons   =       6.6  19.0%          18.9%
    Raw Variance explained by items     =      10.0  28.9%          28.6%
  Raw unexplained variance (total)      =      18.0  52.1% 100.0%   52.5%
    Unexplned variance in 1st contrast  =       3.6  10.3%  19.8%
    Unexplned variance in 2nd contrast  =       2.5   7.3%  14.1%
    Unexplned variance in 3rd contrast  =       2.1   5.9%  11.4%
    Unexplned variance in 4th contrast  =       1.7   4.8%   9.3%
```

VII. RESEARCH FINDINGS

Based on Table 7, the total number of the sample for the control group was 65 consisting of 30 male students (46.2%) and 35 female students (53.8%). Meanwhile, 66 participants consisting of 27 male students (41.0%) and 39 female students (59.0%) were in the treatment group. Each student in the control and treatment groups followed two different learning methods. The students in the control group followed conventional learning methods, while the students in the treatment group received interventions from FCLS activities. The students in the control group who underwent the conventional method learnt the Isometric topic by using textbooks, power point presentations, workbooks and worksheets. The learning activities for the control group took place in the fully physical classroom environment. Meanwhile, the treatment group followed the FCLS activities in which the content of the topic was introduced before the learning took place. The students in the treatment group used the knowledge they gained during the activities in the classroom.

TABLE 7. Demographic information of the sample.

Sample	Group			
	Control		Treatment	
	n	%	n	%
Male	30	46.2	27	41.0
Female	35	53.8	39	59.0
Total	65	100	66	100

A. ANALYSIS OF NORMALITY

The normality test analysis was carried out in order to determine whether the data collected from the sample was normally distributed or not. There are several ways to conduct the normality test such as Skewness, Kurtosis, Kolmogrov-Smirnov (KS), Anderson-Darling, Cramer-von Mises, Lilliefors statistics and Shapiro-Wilk tests [83]. In the context of this study, the Kolmogorov-Smirnov and Shapiro-Wilk analyses were carried out because the number of samples involved in this study was 131, which was included in the range given, i.e., n>50 for Kolmogorov-Smirnov [109], and $3 \leq n \leq 5000$ for Shapiro-Wilk [110]. Table 8 shows the analysis based on the Kolmogorov-Smirnov and Shapiro-Wilk normality tests for the control and treatment groups.

Based on Table 8, it can be observed that the significant value of Kolmogorov-Smirnov and Shapiro-Wilk for all Isometric Transformation HOTS pre- and post-tests is 0.00, which is smaller than the value of 0.05. This shows that the data is not normally distributed. Therefore, the appropriate inference analysis used to answer the third research question was the analysis with non-parametric tests. The selection of each analysis for all tests for the control and treatment groups is summarized in Fig. 3 below.

Based on Fig. 3, the Mann-Whitney and Wilcoxon tests were used to answer the research questions of the study.

B. STUDENTS' HOTS IN THE FOUR LEVELS OF THINKING BETWEEN THE TREATMENT GROUP AND THE CONTROL GROUP

1) THE PRE-TEST FOR CONTROL GROUP AND TREATMENT GROUP

The Mann-Whitney test was used to analyze the pre-HOTS test in terms of the four levels of thinking for the control and treatment groups involving 131 samples. This test was performed because the sample consisted of two different

TABLE 8. **Analysis of normality test for control group and treatment group.**

		Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Pre-Isometric Transformation HOTS Test							
HOTS Pre-Applying Test	Control	0.354	65	.000	.780	65	.000
	Treatment	0.315	66	.000	.714	66	.000
HOTS Pre-Analyzing Test	Control	0.340	65	.000	.728	65	.000
	Treatment	0.379	66	.000	.628	66	.000
HOTS Pre-Evaluating Test	Control	0.425	65	.000	.498	65	.000
	Treatment	0.468	66	.000	.490	66	.000
HOTS Pre-Creating Test	Control	0.539	65	.000	.166	65	.000
	Treatment	0.534	66	.000	.103	66	.000
HOTS Overall Pre-Test	Control	0.208	65	.000	.838	65	.000
	Treatment	0.202	66	.000	.820	66	.000
Post-Isometric Transformation HOTS Test							
HOTS Post-Applying Test	Control	0.320	65	.000	.780	65	.000
	Treatment	0.330	66	.000	.719	66	.000
HOTS Post-Analyzing Test	Control	0.119	65	.024	.945	65	.006
	Treatment	0.234	66	.000	.813	66	.000
HOTS Post-Evaluating Test	Control	0.308	65	.000	.684	65	.000
	Treatment	0.203	66	.000	.880	66	.000
HOTS Overall Post-Test	Control	0.302	65	.000	.786	65	.000
	Treatment	0.190	66	.000	.852	66	.000

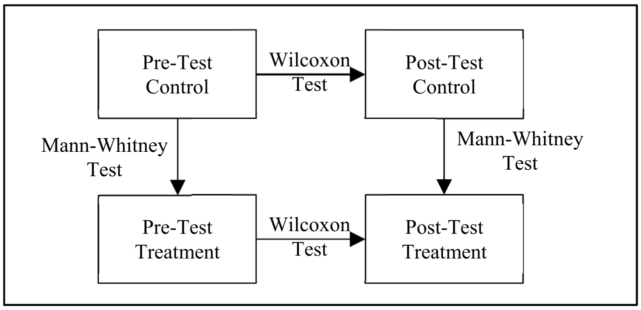


FIGURE 3. **Analysis used to examine the difference between the control group and the treatment group.**

TABLE 9. **Mann-Whitney test analysis for pre-control and pre-treatment groups.**

Level	Group	N	Mean Rank	Significant Value
Applying	Pre-Control	65	65.14	.766
	Pre-Treatment	66	66.85	
Analyzing	Pre-Control	65	69.43	.237
	Pre-Treatment	66	62.62	
Evaluating	Pre-Control	65	68.69	.267
	Pre-Treatment	66	63.35	
Creating	Pre-Control	65	66.52	.552
	Pre-Treatment	66	65.49	

groups. Table 9 shows the Mann-Whitney test analysis for the pre-control and pre-treatment groups.

Based on Table 9, the results show that the significant value for the HOTS test across all four HOTS levels is greater than the alpha value of 0.05. This shows that the null hypothesis failed to be rejected. Therefore, it can be concluded that there is no significant difference between the control group and the treatment group for all thinking levels in the pre-HOTS test.

TABLE 10. **Wilcoxon test analysis for the pre-post control and treatment groups.**

					Value
Applying	Control	Pre-Post	65	14.18	.000
				28.13	
	Treatment	Pre-Post	66	0.00	.000
				32.50	
Analyzing	Control	Pre-Post	65	13.83	.000
				30.35	
	Treatment	Pre-Post	66	.00	.000
				33.50	
Evaluating	Control	Pre-Post	65	20.75	.857
				14.24	
	Treatment	Pre-Post	66	1.50	.000
				28.99	
Creating	Control	Pre-Post	65	.00	.000
				23.00	
	Treatment	Pre-Post	66	.00	.000
				26.00	

2) PRE-POST TEST FOR CONTROL GROUP AND TREATMENT GROUP

The Wilcoxon test was carried out to analyze the pre-post tests of HOTS for the control group involving 65 samples and the pre-post tests of HOTS for the applying level for the treatment group involving 66 samples. The Wilcoxon test was performed because these data involved samples from the same group. The analysis of the Wilcoxon for the control and treatment groups is shown in Table 10.

Based on Table 10, the results show that the significant value for the HOTS test of the control group's applying, analyzing and creating levels is p=.000, which is smaller than the alpha value of 0.05 (p=.000<.05) but not for the evaluating level.

For the treatment group, a significant result (p=.000) was shown for all thinking levels.

3) THE POST-TEST FOR CONTROL GROUP AND TREATMENT GROUP

The Mann-Whitney test was used to analyze the post-HOTS test for the control and treatment groups involving 131 samples. The Mann-Whitney test was used because these data involved samples from two different groups. The Mann-Whitney test for the post-control and post-treatment groups is shown in Table 11.

TABLE 11. **Mann-Whitney test analysis for the applying level for the post-control and post-treatment groups.**

Applying	Post-Control	65	46.26	.000
	Post-Treatment	66	85.44	
Analyzing	Post-Control	65	39.18	.000
	Post-Treatment	66	92.41	
Evaluating	Post-Control	65	43.88	.000
	Post-Treatment	66	87.79	
Creating	Post-Control	65	50.45	.000
	Post-Treatment	66	81.32	

Based on Table 11, the results show that the significant value for the HOTS test in all thinking levels is p=.000, which is smaller than the alpha value of 0.05 (p=.000<.05). Thus, the null hypothesis is rejected. It can be observed that there is a significant difference between the control group and the treatment group for all thinking levels in the post-HOTS test.

C. *STUDENTS' OVERALL HOTS LEVEL BETWEEN THE TREATMENT GROUP AND THE CONTROL GROUP*

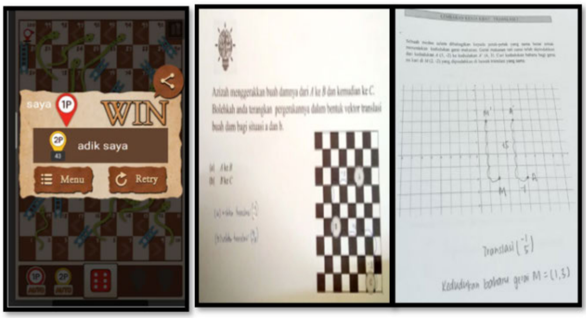
1) OVERALL PRE-HOTS TEST AND POST-HOTS TEST FOR CONTROL GROUP AND TREATMENT GROUP

The Mann-Whitney test was used to analyze the pre-HOTS test for the topic of Isometric Transformation from the overall achievement for the control group and the treatment group involving 131 samples. This test used samples from two different groups, the control group and the treatment group. Table 12 shows the overall Mann-Whitney test analysis for the pre-control and pre-treatment groups.

TABLE 12. **Mann-Whitney Test analysis for overall pre-control and pre-treatment groups.**

Group	N	Mean Rank	Significant Value
Pre-Control	65	70.75	.146
Pre-Treatment	66	61.32	
Post-Control	65	36.84	.000
Post-Treatment	66	94.72	

Based on Table 12, the results show that the significant value for the HOTS Isometric Transformation test in the control group is p=.146, which is greater than the alpha value of 0.05 (p=.146>.05). Therefore, the null hypothesis failed to be rejected. It can be observed that there is no significant difference between the control group and the treatment group in the overall pre-HOTS test. The results show a significant value for the Isometric Transformation HOTS test for the treatment group (p=.000), which is smaller than the alpha value of 0.05 (p=.000<.05). Thus, the null hypothesis is rejected. It can be seen that there is a significant difference between the control group and the treatment group for the overall post-test HOTS.



Azizah menggerakkan buah damnya dari A ke B dan kemudian ke C. Bolehkah anda terangkan pergerakannya dalam bentuk vektor translasi buah dam bagi situasi a dan b.

Translasi $\begin{pmatrix} -1 \\ 5 \end{pmatrix}$

Kedudukan baharu gerai M = (1,3)

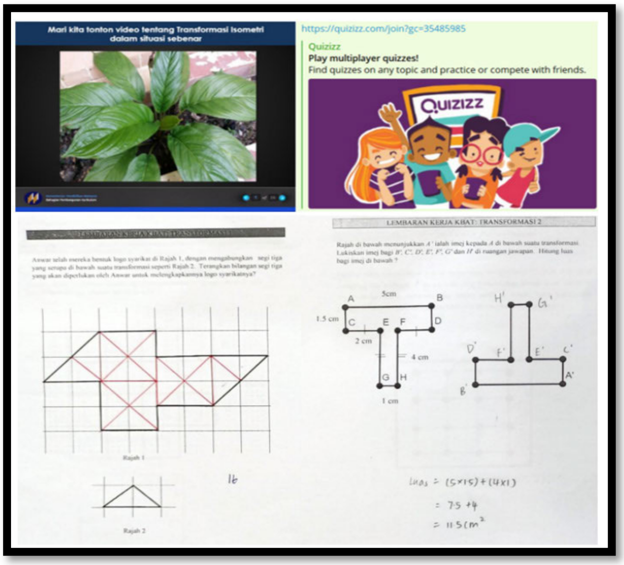
FIGURE 4. **Example of the students' response for the applying level.**

VIII. DISCUSSION

A. *THE APPLYING LEVEL IN THE TOPIC OF ISOMETRIC TRANSFORMATION*

The findings of the study show that the implementation of FCLS can improve the applying level in the topic of Isometric Transformation. The improvement of students' HOTS from the aspect of the applying in the topic of Isometric Transformation not only has a positive impact but also accords well with the claim in [45] in which the authors state that students are more successful in solving Isometric Transformation problems in new situations. This happens because FCLS contains various activities during learning sessions either outside or inside the classroom which can have a positive impact on the students' mastery of HOTS from the applying level for the topic of Isometric Transformation. This is supported through the game methods during learning periods outside the classroom in FCLS.

The game methods related to daily life are given during learning sessions outside the classroom. For example, students play DAM digitally or non-digitally and are required to take pictures and upload them in Google Classroom or WhatsApp. This game method has indirectly helped students understand translation concepts related to their daily life. This is in line with the claim in [111] in which the authors state that the use of game elements in the learning process can motivate students to complete challenging exercises, unlike those students who are not involved in game elements. Moreover, [76] also state that the element of games in flipped classrooms improves problem-solving skills in learning mathematics. Therefore, the results of this study show that there is a significant improvement in the students' HOTS from the applying level for the topic of Isometric Transformation. This proves that FCLS is indeed able to help improve students' HOTS from the aspect of the applying level for the topic of Isometric Transformation.


Mari kita tonton video tentang Transformasi Isometri dalam situasi sebenar

https://quizizz.com/join?gc=35485985

Quizizz

Play multiplayer quizzes!

Find quizzes on any topic and practice or compete with friends.

Anwar telah mereka bentuk logo syarikat di Rajah 1, dengan menggabungkan segi tiga yang serupa di bawah suatu transformasi seperti Rajah 2. Terangkan bilangan segi tiga yang akan diperlukan oleh Anwar untuk melengkapkannya logo syarikatnya?

LEMBARAN KERJA KBAT: TRANSFORMASI 2

Rajah di bawah menunjukkan A' ialah imej kepada A di bawah suatu transformasi. Lukiskan imej bagi B', C', D', E', F', G' dan H' di ruangan jawapan. Hitung luas bagi imej di bawah ?

$\text{Luas} = (5\times1.5)+(4\times1)$

$= 7.5 + 4$

$= 11.5\,\text{cm}^2$

FIGURE 5. Example of the students' response for the analyzing level.

B. THE ANALYZING LEVEL IN THE TOPIC OF ISOMETRIC TRANSFORMATION

The findings of the study prove that the implementation of FCLS can improve the analyzing level in the topic of Isometric Transformation. The increase in HOTS in the treatment group shows that the implementation of FCLS provides a way for students to use analytical skills in assignments to categorize, differentiate, compare, and solve problems in the topic of Isometric Transformation with the help of peers. This is supported through the implementation of group activities during learning periods in the classroom. In this way, students can interact with group members and learn with more skilled friends to avoid misconceptions in the topic. This indirectly shows that students try to avoid misconceptions and promote the improvement of students' mastery of HOTS in the topic of Isometric Transformation [78].

The findings of this study are in line with the findings by [112] which states that with the help of peers, students can solve mathematics problems accurately. Moreover, [113], on the other hand, claim that the method of obtaining the answer to mathematics questions by peers is different from the way the teachers present it. This finding also coincides with the study by [114] who states that, through discussions in small groups, students can understand a concept in greater depth and can explain it to other friends.

As explained in the Social Constructivism Theory which emphasizes teacher guidance, peers in the implementation of FCLS can play a role in helping students understand mathematics concepts. This is particularly critical when students learn outside the classroom in which they can use the Internet to answer the quizzes given. If students are not confident with the answers obtained, they can discuss with their peers, teachers or refer to the Internet. This finding is supported in [115] in which the authors prioritize the Social Constructivism theory in the implementation of flipped classrooms and peer guidance that help develop students' potential in learning mathematics.

The authors in [116] also support the findings of the current study by asserting that learning outside the classroom creates the value of cooperation and mutual help between peers and teachers. Collaborative learning between excellent, average and weak students in a group can improve students' understanding [117]. The value of this collaboration can encourage students to think positively about mathematics and motivate them to learn mathematics in a better way [118].

C. THE EVALUATING LEVEL IN THE TOPIC OF ISOMETRIC TRANSFORMATION

The findings of the current study show that the implementation of FCLS can improve the evaluating level in the topic of Isometric Transformation. The increase of HOTS in the treatment group proves that the implementation of FCLS provides space for students to make generalizations about transformation patterns by using different learning strategies linked to their daily life in the topic of Isometric Transformation. This is consistent with the claim reported in [44] in which the authors support communication skills in learning outside or inside the classroom. This method helps other groups to evaluate ideas or information related to the topic of Isometric Transformation. This is further supported through the project method implemented outside the classroom in FCLS.The project method for the rotation sub-topic is given in the form of a video to the students. They are required to use recycled items to make a project and upload them in Google Classroom or WhatsApp. This project method has indirectly helped students understand the concept of rotation related to their daily life. Likewise, the same finding was found in [65], i.e, project-based learning in FCLS helps students apply mathematical concepts in their daily life. The findings of this study prove that the implementation of FCLS can have a positive impact [115] on students' mastery of HOTS from the aspect of the evaluating level for the topic of Isometric Transformation. This process is implemented through watching videos and answering quiz questions for the concept of rotation before class to help students make connections to the topics. Then, this process is followed by the second phase of applying and strengthening the concept through the continuation of learning outside the classroom. Students, then, answer the applying and analyzing questions followed by the evaluating questions through group discussions. Communicating with group members is in line with the claim laid out in [71] in which the author asserts that group presentations allow students to exchange opinions on new knowledge and ultimately build their thinking skills, knowledge and assessment skills [74].

This finding proves that FCLS can stimulate students' assessment skills. In this way, students can communicate with group members and learn with friends who are more skilled to answer questions in the assessment aspect [57]. Therefore, project-based learning before class in FCLS helps

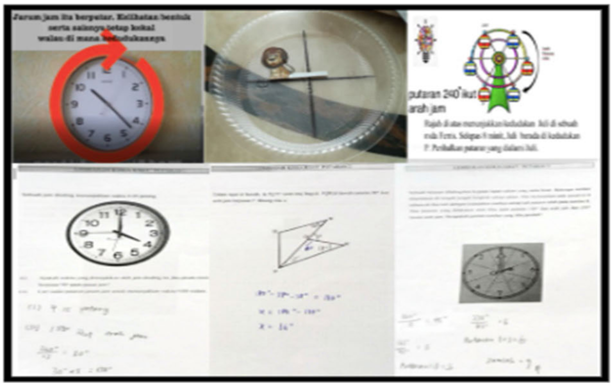


FIGURE 6. Example of the students' response for the evaluating level.

students answer HOTS questions easily. In the current study, the students who went through this intervention explained that the various activities related to their daily life brought about cognitive changes and increased their HOTS mastery.

The findings of this study are also in line with the claim in [119] in which the author states that FCLS in learning mathematics contributes to the cognitive development of students without time constraints. This FCLS is student-centered and provides maximum opportunities for students to use their time to understand mathematics concepts [120]. Moreover, [121] and [122] also agree that FCLS helps students improve their understanding in learning mathematics. Likewise, [123] explain that teaching aids make students more confident in learning mathematics, especially in the topic of Isometric Transformation.

Furthermore, [124] emphasize that creative teaching aids and visual tools can stimulate students' creative thinking. The findings of the current study support previous studies that show a positive relationship between teaching aids and student's mastery of HOTS [125]. The finding also shows that FCLS can improve the mastery of students' HOTS from the aspect of the evaluating level for the topic of Isometric Transformation. This clearly proves that FCLS is more successful in influencing students' HOTS mastery from the aspect of the evaluating level for the Isometric Transformation topic compared to the control group who applies conventional learning strategies.

D. THE CREATING LEVEL IN THE TOPIC OF ISOMETRIC TRANSFORMATION

The findings of the study show that the implementation of FCLS can improve the creating level in the topic of Isometric Transformation. The increase of HOTS in the treatment group proves that the implementation of FCLS provides space for students to use their cognitive skills to connect ideas and build new forms in the answer space. This is supported through communication skills in learning outside and inside the classroom. This environment demands students to present answers to other groups so that they can evaluate ideas or information related to the topic of Isometric Transformation.

The findings of this study also show that the implementation of FCLS can have a positive impact on the mastery of students' HOTS from the aspect of the creating level for the topic of Isometric Transformation [126]. For example, the sub-topics of Translation, Reflection and Rotation as Isometry are introduced to learning outside the classroom by providing videos related to daily life [127]. Next, the learning process is followed by quiz questions for the concept of Translation, Reflection and Rotation as Isometry before the class starts in order to test the level of students' understanding. This will make teachers more prepared and face various questions from students more effectively. Then, this process is followed by the second phase of applying and strengthening the concept through the continuation of learning outside the classroom. Students complete a comprehensive exercise that focuses on applying, analyzing, and evaluating. This is followed by creating questions through group discussions until they successfully create a form and provide justifications. This finding also proves that FCLS can stimulate students' creative skills [128].

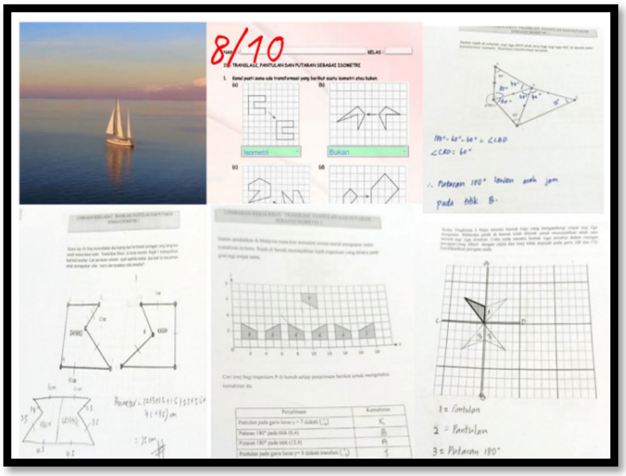


FIGURE 7. Example of the students' response for the creating level.

Collaborative efforts among students and teachers through 21st century learning can help students answer creative questions. Therefore, collaborative learning that exists in FCLS can help students answer HOTS questions easily. This finding is in line with [129] who states that continuous learning and collaborative skills in group activities can help improve students' mastery of HOTS. Likewise, [130] asserts that FCLS is critical in the development and implementation of learning activities.

E. STUDENTS' OVERALL HOTS IN THE TOPIC OF ISOMETRIC TRANSFORMATION

The findings of the current study show that the implementation of FCLS can significantly increase the students' mastery of HOTS as a whole in the topic of Isometric Transformation. The increase of HOTS in the treatment group proves that the implementation of FCLS gives space for students to use their cognitive skills. This is supported through collaborative efforts in learning outside and inside the classroom. FCLS is a strategy that prioritizes HOTS inside and outside the classroom [89], [127]. HOTS is necessary for each student at every level of education and in every subject [131]. Mathematics also prioritizes HOTS. The implementation of HOTS in learning mathematics aims to change students' perception and increase their interest in learning mathematics [132]. Therefore, the researchers used FCLS as a strategy to develop HOTS inside and outside the classroom.

As suggested by [68], teachers need to focus on the implementation of FCLS, especially before learning begins. Moreover, [133] explain in detail the implementation of FCLS through videos. In their study, videos are used to explain each sub-topic, such as translation, reflection and rotation, in the context of students' daily life. This in turn helps students relate their knowledge and skills in obtaining mathematical information [37]. For example, the sub-topic of Rotational Symmetry is introduced by providing videos related to students' daily life. Next, this activity is followed by a quiz for the concept of Rotational Symmetry before the class starts so that it will be easier for students to apply their knowledge. Moreover, [134] also support the method of giving quizzes in FCLS so that students are given opportunities to improve their problem-solving skills.

Then, this process is followed by the second phase of applying and strengthening the concept through the continuation of learning outside the classroom. Students answer the applying, analyzing, evaluating, and creating questions through group discussions until they successfully create the given tiles. Comprehensive training that focuses on HOTS has clearly proven to help students improve their mastery of HOTS.

The statement above clearly shows that students are more likely to use FCLS in their learning strategies. Specifically, this FCLS helps students understand the Isometric Transformation topic in greater depth [135]. FCLS can enhance the relationship between teachers and students when students need guidance. Students can get help from teachers or more skilled people through social media [136] without time constraints. Furthermore, [137] assert that FCLS provides more time for active learning and problem-solving activities. Likewise, [138] states that FCLS can increase creativity and stimulate knowledge to solve HOTS problems.

IX. CONCLUSION

The current study provides meaningful theoretical and practical implications. The development of the Flipped Classroom Learning Strategy (FCLS) for the improvement of HOTS in the Isometric Transformation topic can be used as a guide to manage mathematics learning more effectively. The implications of this study can be divided into two parts, which are theoretical implications and practical implications. FCLS has integrated the Theory of Social Constructivism in the learning of mathematics, especially for the topic of Isometric Transformation. Based on the findings of the study, the use of FCLS has succeeded in significantly increasing students' mastery of HOTS. FCLS prioritizes student-centered learning and does not encourage conventional learning to deepen the topic of Isometric Transformation. This is so because every learning activity prioritizes integration with other people with more skills based on the principle of the Zone of Proximal Development (ZPD). This is achieved through watching videos, accessing additional notes, and group discussions. The three phases in FCLS emphasize student-centered learning activities to increase students' understanding in the topic of Isometric Transformation and provide opportunities for students to interact socially with their teachers and peers. FCLS has given implications in general to teachers' pedagogical practices that focus on the construction of students' mathematics HOTS knowledge in the topic of Isometric Transformation. FCLS is equipped with a lesson plan and a guide in conducting various methods. Comprehensive training on HOTS will make it easier for teachers to integrate HOTS in their classroom. FCLS helps teachers to attract students' attention, interest and confidence in the topic of Isometric Transformation. Nevertheless, the effectiveness of FCLS depends on the expertise of teachers in choosing appropriate skills. Teaching resources not only increase students' mastery of HOTS in the topic of Isometric Transformation, but also produce quality mathematics teachers. This indirectly supports 21st century pedagogic practices that promote ICT skills and diversity in knowledge delivery techniques, which are in line with MOE's objectives

REFERENCES

[1] C. A. Agger and A. C. Koenka, "Does attending a deeper learning school promote student motivation, engagement, perseverance, and achievement?" *Psychol. Schools*, vol. 57, no. 4, pp. 627–645, Apr. 2020.

[2] *Standard Document of Curriculum and Assessment for Form Two Mathematics Curriculum*, Ministry Educ. Malaysia, Bahagian Pembanguna Kurikulum, Putrajaya, Malaysia, 2016.

[3] B. Bourke, "Using gamification to engage higher-order thinking skills," in *Handbook of Research on Promoting Higher-Order Skills and Global Competencies in Life and Work*, J. Keengwe and R. Byamukama, Eds. Hershey, PA, USA: IGI Global, 2019, pp. 1–21.

[4] B. M. Chang, "Korea's English education policy innovations to lead the nation into the globalized world," *J. Pan-Pacific Assoc. Appl. Linguist.*, vol. 13, no. 1, pp. 83–97, 2009.

[5] M. Kim, "Teaching and learning in Korean classrooms: The crisis and the new approach," *Asia Pacific Educ. Rev.*, vol. 4, no. 2, pp. 140–150, Jun. 2003.

[6] B. Kaur, "Evolution of Singapore's school mathematics curriculum," in *School Mathematics Curricula: Asian Perspectives and Glimpses of Reform*. Singapore: Springer, 2019, pp. 24–36.

[7] *Pelan Pembangunan Pendidikan Malaysai 2013–2025: Laporan Tahunan 2017*, Ministry Educ. Malaysia, Putrajaya, Malaysia 2018.

[8] N. S. Ahmad Alhassora, M. S. Abu, and A. H. Abdullah, "Inculcating higher-order thinking skills in mathematics: Why is it so hard," *Man India*, vol. 97, no. 13, pp. 51–62, 2017.

[9] *Laporan Analisis Keputusan Sijil Pelajaran Malaysia (SPM) Tahun 2019*, Malaysian Examinations Board, Putrajaya, Malaysia, 2019.

[10] A. Y. M. Arshad and R. M. Yasin, "Higher-order thinking skills among students in solving problem for science subject," *Asian Educ. Action Res. J.*, vol. 4, no. 1, pp. 81–96, 2015.

[11] S. Bankole, "Developing critical thinking skills in students: A mandate for higher education in Nigeria," *Eur. J. Educ. Res.*, vol. 1, no. 2, pp. 155–161, Apr. 2012.

[12] T. K. F. Chiu and I. A. C. Mok, "Learner expertise and mathematics different order thinking skills in multimedia learning," *Comput. Educ.*, vol. 107, pp. 147–164, Apr. 2017.

[13] N. Ramlee, M. S. Rosli, and N. S. Saleh, "Mathematical HOTS cultivation via online learning environment and 5E inquiry model: Cognitive impact and the learning activities," *Int. J. Emerg. Technol. Learn.*, vol. 14, no. 24, pp. 140–151, 2019.

[14] Malaysian Ministry of Education, Putrajaya, Malaysia. (2012). *Preliminary Report Malaysia Education Blueprint 2013–2025*. [Online]. Available: http://www.moe.gov.my/userfiles/file/PPP/Preliminary-Blueprint-Eng.pdf

[15] *Education at a Glance 2010 OECD Indicators*, Org. Econ. Co-Oper. Develop., Paris, France, 2010.

[16] I. V. S. Mullis, M. O. Martin, P. Foy, and A. Arora, *TIMSS 2011 International Results in Mathematics*. Chestnut Hill, MA, USA: TIMSS & PIRLS International, 2012.

[17] N. Ngah, Z. Ismail, Z. Tasir, and M. N. H. M. Said, "Students' higher order thinking skills and their relationships with problem posing ability," *Adv. Sci. Lett.*, vol. 23, no. 4, pp. 2876–2879, Apr. 2017.

[18] C. B. Gek, "Pengetahuan dan pengaplikasian kemahiran berfikir aras tinggi dalam kalangan guru teknik dan vokasional," Ph.D. thesis, Dept. Educ., Universiti Tun Hussein Onn Malaysia, Parit Raja, Malaysia, 2017.

[19] I. Hazram and N. H. Nurulain, "Pengintegrasian KBAT dalam pengajaran Matematik semasa praktikum dalam kalangan bakal guru sekolah rendah," *J. Adv. Res. Soc. Behav. Sci.*, vol. 1, no. 1, pp. 80–89, 2020.

[20] N. Kassim and E. Zakaria, "Integrasi kemahiran berfikir aras tinggi dalam pengajaran dan pembelajaran matematik: Analisis keperluan guru," in *Proc. Counseling Centre Profesional Counselor Educ. Lab.* Medan, Indonesia: State Univ. Medan, 2015.

[21] I. A. M. M. Som and Z. Haron, "Kesediaan guru mengimplementasikan KBAT dalam pembelajaran dan pengajaran matematik sekolah rendah," *J. Penyelidikan Pendidikan*, vol. 18, pp. 147–159, 2017.

[22] N. S. Misrom, M. S. Abdurrahman, A. H. Abdullah, S. Osman, M. H. Hamzah, and A. Fauzan, "Enhancing students' higher-order thinking skills (HOTS) through an inductive reasoning strategy using geogebra," *Int. J. Emerg. Technol. Learn.*, vol. 15, no. 3, pp. 156–179, 2020, doi: 10.3991/ijet.v15i03.9839.

[23] R. Collins, "Skills for the 21st century: Teaching higher-order thinking," *Curriculum Leadership J.*, vol. 12, no. 14, pp. 1–7, 2014.

[24] M. H. Yee, J. M. Yunos, W. Othman, R. Hassan, T. K. Tee, and M. M. Mohamad, "Disparity of learning styles and higher order thinking skills among technical students," *Proc. Social Behav. Sci.*, vol. 204, pp. 143–152, Aug. 2015.

[25] L. E. Richland and K. N. Begolli, "Analogy and higher order thinking: Learning mathematics as an example," *Policy Insights from Behav. Brain Sci.*, vol. 3, no. 2, pp. 160–168, Oct. 2016.

[26] A. H. Abdullah, N. L. Z. Abidin, and M. Ali, "Analysis of students' errors in solving higher order thinking skills (HOTS) problems for the topic of fraction," *Asian Social Sci.*, vol. 11, no. 21, pp. 133–142, Jul. 2015.

[27] C. J. Lin and G. J. Hwang, "A learning analytics approach to investigating factors affecting EFL students' oral performance in a flipped classroom," *J. Educ. Technol. Soc.*, vol. 21, no. 2, pp. 205–219, 2018.

[28] S. H. Mun, A. H. Abdullah, M. Mokhtar, D. F. Ali, N. F. Jumaat, Z. M. Ashari, N. A. Samah, and K. A. A. Rahman, "Active learning using digital smart board to enhance primary school students' learning," *Int. J. Interact. Mobile Technol.*, vol. 13, no. 7, pp. 4–16, Jul. 2019, doi: 10.3991/ijim.v13i07.10654.

[29] J. Y. Foo, M. F. N. L. Abdullah, N. H. Adenan, and J. Y. Hoong, "Kajian keperluan pembangunan modul latihan berasaskan kemahiran berfikir aras tinggi bagi topik ungkapan algebra tingkatan satu," *Jurnal Pendidikan Bitara UPSI*, vol. 14, pp. 33–40, Apr. 2021.

[30] G. S. Aktaş and M. Ünlü, "Understanding of eight grade students about transformation geometry: Perspectives on Students' mistakes," *J. Educ. Training Stud.*, vol. 5, no. 5, p. 103, Apr. 2017.

[31] L. D. Edwards, "Exploring the territory before proof: Students' generalization in a computer microworld for transformation geometry," *Int. J. Comput. Math. Learn.*, vol. 1, pp. 187–215, Oct. 1997.

[32] A. Z. A. Syawallina, "Pembinaan transformation geoboard sebagai alat bantu mengajar untuk tajuk transformasi isometri tingkatan dua," Fakulti Sains Matematik, Universiti Pendidikan Sultan Idris, Tanjung Malim, Malaysia, 2021.

[33] *Commission on Standards for School Mathematics: Curriculum and Evaluation Standards for School Mathematics*, Nat. Council Teachers Math., Reston, VA, USA, 1989.

[34] *Analisis Prestasi Murid Matematik TIMSS 2015. Educational Policy Planning and Research Division (EPRD)*, Ministry Educ. Malaysia, Putrajaya, Malaysia, 2017.

[35] S. Johansson and R. Strietholt, "Globalised student achievement? A longitudinal and cross-country analysis of convergence in mathematics performance," *Comparative Educ.*, vol. 55, no. 4, pp. 536–556, Oct. 2019.

[36] B. Guven, "Using dynamic geometry software to improve eight grade students' understanding of transformation geometry," *Australas. J. Educ. Technol.*, vol. 28, no. 2, pp. 364–382, Apr. 2012.

[37] R. K. N. Karimah, T. A. Kusmayadi, and I. Pramudya, "Analysis of difficulties in mathematics learning on students with guardian personality type in problem-solving HOTS geometry test," *J. Phys., Conf. Ser.*, vol. 1008, Apr. 2018, Art. no. 012076.

[38] A. Watungwa, "An investigation into the teaching and learning of geometrical transformation: A case study of secondary schools in Masvingo district, Zimbabwe," Ph.D. dissertation, Dept. Educ., Bindura Univ. Sci. Educ., Bindura, Zimbabwe, 2017.

[39] M. H. Karadeniz, T. B. Kaya, and F. Bozkus, "Explanations of prospective middle school mathematics teachers for potential misconceptions on the concept of symmetry," *Int. Electron. J. Elementary Educ.*, vol. 10, no. 1, pp. 71–82, Sep. 2017.

[40] R. B. Armah and P. S. Kissi, "Use of the van hiele theory in investigating teaching strategies used by college of education geometry tutors," *EURASIA J. Math., Sci. Technol. Educ.*, vol. 15, no. 4, Jan. 2019, Art. no. em1694.

[41] H. B. Yanik, "Prospective middle school mathematics teachers' preconceptions of geometric translations," *Educ. Stud. Math.*, vol. 78, no. 2, pp. 231–260, Nov. 2011.

[42] H. B. Yanik, "Middle-school students' concept images of geometric translations," *J. Math. Behav.*, vol. 36, pp. 33–50, Dec. 2014.

[43] M. A. Al-Khateeb, "The extent of mathematics teacher's awareness of their students' misconceptions in learning geometrical concepts in the intermediate education stage," *Eur. Sci. J.*, vol. 12, no. 31, pp. 357–372, 2016.

[44] X. Yao and A. Manouchehri, "Middle school students' generalizations about properties of geometric transformations in a dynamic geometry environment," *J. Math. Behav.*, vol. 55, Sep. 2019, Art. no. 100703.

[45] G. S. Aktaş and M. Ünlü, "Understanding of eight grade students about transformation geometry: Perspectives on students' mistakes," *J. Educ. Train. Stud.*, vol. 5, no. 5, pp. 103–119, 2017.

[46] N. S. Rajendran, "Pengajaran kemahiran berfikir aras tinggi: Kesediaan guru mengendalikan proses pengajaran pembelajaran," in *Proc. Seminar/Pameran Projek KBKK, Poster Warisan-Pendidikan-Wawasan*. Putrajaya, Malaysia: Kementerian Pendidikan Malaysia, 2001, pp. 1–13.

[47] D. Evbuomwan, "An investigation into the difficulties faced by form C students in the learning of transformation geometry in Lesotho secondary schools," M.S. thesis, Dept. Educ., Univ. South Africa, Pretoria, South Africa, 2013.

[48] A. Özerem, "Misconceptions in geometry and suggested solutions for seventh grade students," *Proc. Social Behav. Sci.*, vol. 55, pp. 720–729, Oct. 2012.

[49] J. Bergmann and A. Sams, *Flip Your Classroom: Reach Every Student in Every Class Every Day*. Eugene, OR, USA: International Society for Technology in Education, 2012.

[50] C. S. Tan, N. Zakuan, and M. I. A. Aziz, "Recent trends of blended learning and flipped classroom in Malaysia," *Arab World English J.*, pp. 290–301, 2022.

[51] A. A. Rahman, B. Aris, H. Mohamed, N. Zaid, and Z. Abdullah, "Flipped classroom dalam konteks Malaysia," in *Proc. Konvensyen Antarabangsa Jiwa Pendidik*, 2014.

[52] Q.-F. Yang, C.-J. Lin, and G.-J. Hwang, "Research focuses and findings of flipping mathematics classes: A review of journal publications based on the technology-enhanced learning model," *Interact. Learn. Environ.*, vol. 29, no. 6, pp. 905–938, Aug. 2021.

[53] C. K. Lo, C. W. Lie, and K. F. Hew, "Applying 'first principles of instruction' as a design theory of the flipped classroom: Findings from a collective study of four secondary school subjects," *Comput. Educ.*, vol. 118, pp. 150–165, Mar. 2018.

[54] C.-Y. Hung, J. C.-Y. Sun, and J.-Y. Liu, "Effects of flipped classrooms integrated with MOOCs and game-based learning on the learning motivation and outcomes of students from different backgrounds," *Interact. Learn. Environ.*, vol. 27, no. 8, pp. 1028–1046, Nov. 2019.

[55] S. J. DeLozier and M. G. Rhodes, "Flipped classrooms: A review of key ideas and recommendations for practice," *Educ. Psychol. Rev.*, vol. 29, no. 1, pp. 141–151, Mar. 2017.

[56] G.-H. Chen and C.-Y. Su, "Investigating the effects of flipped learning, student question generation, and instant response technologies on students' learning motivation, attitudes, and engagement: A structural equation modeling," *EURASIA J. Math., Sci. Technol. Educ.*, vol. 14, no. 6, pp. 2453–2466, Apr. 2018.

[57] L. Abeysekera and P. Dawson, "Motivation and cognitive load in the flipped classroom: Definition, rationale and a call for research," *Higher Educ. Res. Develop.*, vol. 34, no. 1, pp. 1–14, Jan. 2015.

[58] H. J. Heo and M. R. Choi, "Flipped learning in the middle school math class," *Adv. Sci. Technol. Lett.*, vol. 71, pp. 94–97, 2014.

[59] K.-Y. Lee and Y.-C. Lai, "Facilitating higher-order thinking with the flipped classroom model: A student teacher's experience in a Hong Kong secondary school," *Res. Pract. Technol. Enhanced Learn.*, vol. 12, no. 1, pp. 1–14, Dec. 2017.

[60] L. C. Wolff and J. Chan, *Flipped Classrooms for Legal Education*, vol. 13. New York, NY, USA: Springer, 2016.

[61] A. A. Rahman, N. M. Zaid, B. Aris, Z. Abdullah, H. Mohamed, and H. Van Der Meijden, "Implementation strategy of project based learning through flipped classroom method," in *Proc. IEEE Conf. e-Learn., e-Manag. e-Services (IC3e)*, Oct. 2016, pp. 1–5.

[62] A. A. Rahman, Z. Abdullah, H. Mohammed, N. M. Zaid, and B. Aris, "Flipped classroom: Reviving cognitive development among school students," in *Proc. 3rd Int. Seminar Quality Affordable Educ.*, 2014, pp. 1–5.

[63] T. C. Mukherjee, "Exploring the relationship between learners' attributes and flipped classroom success in the Malaysian context," 2013.

[64] A. H. Abdullah and E. Zakaria, "The activities based on Van Hiele's phase-based learning: Experts' and pre-service teachers' views," *J. Math. Statist.*, vol. 8, no. 3, pp. 385–395, 2012, doi: 10.3844/jmssp.2012.385.395.

[65] A. A. Rahman, "Kesan kaedah flipped classroom menerusi pembelajaran berasaskan projek ke atas pencapaian dan gaya pembelajaran pelajar," Ph.D. thesis, Fakulti Pendidikan, Universiti Teknologi Malaysia, Johor Bahru, Malaysia, 2017.

[66] B. Goodwin and K. Miller, "Research says: Evidence on flipped classrooms is still coming," *Educ. Leadership*, vol. 70, no. 6, pp. 78–80, 2013.

[67] I. Shibley, "Putting the learning in blended learning," in *Blended and Flipped: Exploring New Models for Effective Teaching & Learning*, M. Bart, Eds. Madison, WI, USA: Magna Publications, 2014, pp. 4–5.

[68] Z. de Araujo, S. Otten, and S. Birisci, "Teacher-created videos in a flipped mathematics class: Digital curriculum materials or lesson enactments?" *ZDM Int. J. Math. Educ.*, vol. 49, no. 5, pp. 687–699, Oct. 2017.

[69] Z. Luo, B. O'Steen, and C. Brown, "Flipped learning wheel (FLW): A framework and process design for flipped L_2 writing classes," *Smart Learn. Environ.*, vol. 7, no. 1, pp. 1–21, Dec. 2020.

[70] C. Luo, T. K. F. Hew, C.-U. Lei, and E. Oh, "Principle-guided flipped classroom implementation framework for teaching technological contents," in *Proc. IEEE 6th Int. Conf. Teaching, Assessment, Learn. Eng. (TALE)*, Dec. 2017, pp. 449–456.

[71] L. S. Vygotsky, "Interaction between learning and development," *Readings Develop. Child.*, vol. 23, no. 3, pp. 34–41, 1978.

[72] X. Wei, I.-L. Cheng, N.-S. Chen, X. Yang, Y. Liu, Y. Dong, and X. Zhai, "Effect of the flipped classroom on the mathematics perfor- mance of middle school students," *Educ. Technol. Res. Develop.*, vol. 68, no. 3, pp. 1461–1484, Jun. 2020.

[73] K. K. Bhagat, C. N. Chang, and C. Y. Chang, "The impact of the flipped classroom on mathematics concept learning in high school," *J. Educ. Technol. Soc.*, vol. 10, no. 3, pp. 134–142, 2016.

[74] M. Çevikbaş and G. Kaiser, "Student engagement in a flipped secondary Mathematics classroom," *Int. J. Sci. Math. Educ.*, vol. 20, no. 7, pp. 1455–1480, 2022.

[75] L. Cheng, A. D. Ritzhaupt, and P. Antonenko, "Effects of the flipped classroom instructional strategy on students' learning outcomes: A meta-analysis," *Educ. Technol. Res. Develop.*, vol. 67, no. 4, pp. 793–824, Aug. 2019.

[76] C. K. Lo and K. F. Hew, "A comparison of flipped learning with gamification, traditional learning, and online independent study: The effects on students' mathematics achievement and cognitive engagement," *Interact. Learn. Environ.*, vol. 28, no. 4, pp. 464–481, May 2020.

[77] V. Aidinopoulou and D. G. Sampson, "An action research study from implementing the flipped classroom model in primary school history teaching and learning," *J. Educ. Technol. Soc.*, vol. 20, no. 1, pp. 237–247, 2017.

[78] C. Kostaris, S. Sergis, D. G. Sampson, M. N. Giannakos, and L. Pelliccione, "Investigating the potential of the flipped classroom model in K-12 ICT teaching and learning: An action research study," *Educ. Technol. Soc.*, vol. 20, no. 1, pp. 261–273, 2017.

[79] M. Tanner and E. Scott, "A flipped classroom approach to teaching systems analysis, design and implementation," *J. Inf. Technol. Educ. Res.*, vol. 14, pp. 219–241, Jun. 2015.

[80] N. Alias, "Development of pedagogical module based on technology and learning style Felder Silverman for secondary school physics curriculum," Ph.D. thesis, Dept. Educ., Univ. Malaya, Kuala Lumpur, Malaysia, 2010.

[81] J. D. Klien and R. C. Richey, *Design and Development Research: Methods, Strategies, and Issues*. London, U.K.: Lawrence Erlbaum Associates, 2007.

[82] R. C. Richey, J. D. Klein, and W. A. Nelson, "Developmental research: Studies of instructional design and development," in *Handbook of Research on Educational Communications and Technology*, 3rd ed., M. Spector, M. D. Merrill, J. van Merrienboer, and M. P. Driscoll, Eds. New York, NY, USA: Routledge, 2007.

[83] G. Darusalam and S. Hussin, *Metodologi Penyelidikan Dalam Pendidikan: Amalan dan Analisis Kajian*, 2nd ed. Kuala Lumpur, Malaysia: Penerbit Universiti Malaya, 2018.

[84] R. Yilmaz, "Exploring the role of e-learning readiness on student satisfaction and motivation in flipped classroom," *Comput. Hum. Behav.*, vol. 70, pp. 251–260, May 2017.

[85] L. M. Tahir, M. B. Musah, A. H. Abdullah, A. H. Musta'amal, and M. H. A. Abdullah, "Technical college teachers sharing their knowledge: Does leadership, institutional factors or barriers predict their practices?" *Educ. Stud.*, vol. 42, no. 5, pp. 465–492, Oct. 2016, doi: 10.1080/03055698.2016.1230046.

[86] M. S. Knowles, E. F. Holton, and R. A. Swanson, *Learning From Results: A Practical Approach to Increase the Effectiveness of Corporate Education*. Rio de Janeiro, Brazil: Elsevier, 2011.

[87] K. Kumar, C. Chang, and C. Chang, "International forum of educational technology & society the impact of the flipped classroom on mathematics concept learning in high school," *Educ. Technol. Soc.*, vol. 19, no. 3, pp. 134–142, 2015.

[88] R. Talbert, *Flipped Learning: A Guide for Higher Education Faculty*. Sterling, VA, USA: Stylus Publishing, 2017.

[89] G.-J. Hwang, C.-L. Lai, and S.-Y. Wang, "Seamless flipped learning: A mobile technology-enhanced flipped classroom with effective learning strategies," *J. Comput. Educ.*, vol. 2, no. 4, pp. 449–473, 2015.

[90] A. H. Abdullah, N. H. Ibrahim, J. Surif, M. Ali, and M. H. Hamzah, "Non-routine mathematical problems among in-service and pre-service mathematics teachers," in *Proc. IEEE Int. Conf. Teaching, Assessment Learn. Eng. (TALE)*, Wellington, New Zealand, Dec. 2014, pp. 18–24.

[91] J. W. Creswell, *A Concise Introduction to Mixed Methods Research*. Los Angeles, CA, USA: Sage, 2014.

[92] W. M. Holmes, *Using Propensity Scores in Quasi-Experimental Designs*. Los Angeles, CA, USA: Sage, 2014.

[93] W. R. Shadish, J. K. Luellen, and M. H. Clark, "Propensity scores and quasi-experiments: A testimony to the practical side of Lee Sechrest," in *Strengthening Research Methodology: Psychological Measurement and Evaluation*, R. R. Bootzin and P. E. McKnight, Eds. New York, NY, USA: American Psychological Association, 2006, pp. 143–157.

[94] N. H. Ibrahim, J. Surif, A. H. Abdullah, and N. A. S. Sabtu, "Comparison of pedagogical content knowledge between expert and novice lecturers in teaching and learning process," in *Proc. Int. Conf. Teaching Learn. Comput. Eng.*, Kuching, Malaysia, Apr. 2014, pp. 240–246, doi: 10.1109/latice.2014.53.

[95] L. Cohen, L. Manion, and K. Morrison, *Research Methods in Education*. London, U.K.: Routledge, 2011.

[96] D. T. Campbell and J. C. Stanley, "Experimental and quasi-experimental design for research," in *Handbook of Research on Teaching*, N. L. Gage, Ed. Boston, MA, USA: Houghton Mifflin Company, 1963.

[97] D. Ary, L. C. Jacobs, C. K. Sorensen, and D. A. Walker, *Introduction to Research in Education*. Belmont, CA, USA: Cengage Learning, 2014.

[98] D. O. MacDaniel, *Broadcasting in the Malay World*. Norwood, NJ, USA: Ablex, 1994.

[99] J. W. Creswell and J. D. Creswell, *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*, 5th ed. Los Angeles, CA, USA: Sage, 2018.

[100] D. Kurniati, A. R. As'ari, A. H. Abdullah, M. Muksar, and S. Sudirman, "Impact of infusing truth-seeking and open-minded behaviors on mathematical problem-solving," *J. Educ. Gifted Young Scientists*, vol. 7, no. 4, pp. 1019–1036, Dec. 2019.

[101] T. G. Bond and C. M. Fox, *Applying the Rasch Model: Fundamental Measurement in the Human Sciences*. New York, NY, USA: Lawrence Erlbaum Associates Publishers, 2007.

[102] T. G. Bond and C. M. Fox, *Applying the Rasch Model: Fundamental Measurement in the Human Sciences*, 3rd ed. New York, NY, USA: Routledge, 2015.

[103] R. M. Yasin, F. A. N. Yunus, R. C. Rus, A. Ahmad, and M. B. Rahim, "Validity and reliability learning transfer item using Rasch measurement model," *Proc. Social Behav. Sci.*, vol. 204, pp. 212–217, Aug. 2015.

[104] B. Sumintono, "Rasch model measurements as tools in assesment for learning," in *Proc. 1st Int. Conf. Educ. Innov. (ICEI)*, 2018, pp. 38–42.

[105] J. M. Linacre, *A User's Guide to Winsteps: Rasch-Model Computer Program*. Chicago, IL, USA: MESA Press, 2007.

[106] A. A. Aziz, M. S. Masodi, and A. Zaharim, *Asas Model Pengukuran Rasch: Pembentukan Skala Dan Struktur Pengukuran*, 3rd ed. Bangi, Malaysia: Penerbit Universiti Kebangsaan Malaysia, 2017.

[107] J. M. Linacre, *Winsteps Rasch Measurement Computer Program User's Guide*. Beaverton, OR, USA: Winsteps, 2012.

[108] W. P. Fisher, Jr., "Transaction of the Rasch measurement SIG American educational research association," *Rasch Meas. Trans.*, vol. 21, no. 1, pp. 1095–1096, 2007.

[109] I. M. Chakravarti, R. G. Laha, and J. Roy, *Handbook of Methods of Applied Statistics* (Wiley Series in Probability and Mathematical Statistics). New York, NY, USA: Wiley, 1967, pp. 392–394.

[110] N. M. Razali and Y. B. Wah, "Power comparisons of Shapiro–Wilk, Kolmogorov–Smirnov, Lilliefors and Anderson–Darling tests," *J. Stat. Model. Anal.*, vol. 2, no. 1, pp. 21–33, 2011.

[111] K. F. Hew, B. Huang, K. W. S. Chu, and D. K. W. Chiu, "Engaging Asian students through game mechanics: Findings from two experiment studies," *Comput. Educ.*, vol. 92, pp. 221–236, Jan. 2016.

[112] C. Webel, C. Sheffel, and K. A. Conner, "Flipping instruction in a fifth grade class: A case of an elementary mathematics specialist," *Teaching Teacher Educ.*, vol. 71, pp. 271–282, Apr. 2018.

[113] S. McCallum, J. Schultz, K. Sellke, and J. Spartz, "An examination of the flipped classroom approach on college student academic involvement," *Int. J. Teach. Learn. High. Educ.*, vol. 27, no. 1, pp. 42–55, 2015.

[114] J. Van Sickle, "Adventures in flipping college algebra," *Primus*, vol. 25, no. 8, pp. 600–613, Sep. 2015.

[115] M. Çevikbaş and G. Kaiser, "Flipped classroom as a reform-oriented approach to teaching mathematics," *ZDM Int. J. Math. Educ.*, vol. 52, no. 7, pp. 1291–1305, Dec. 2020.

[116] M.-H. Cho and S. Tobias, "Should instructors require discussion in online courses? Effects of online discussion on community of inquiry, learner time, satisfaction, and achievement," *Int. Rev. Res. Open Distrib. Learn.*, vol. 17, no. 2, pp. 123–140, Mar. 2016.

[117] A. H. Abdullah, S. S. Fadil, S. N. S. A. Rahman, L. M. Tahir, and M. H. Hamzah, "Emerging patterns and problems of higher-order thinking skills (HOTS) mathematical problem-solving in the form-three assessment (PT3)," *South Afr. J. Educ.*, vol. 39, no. 2, pp. 1–18, May 2019.

[118] C. Jia, K. F. Hew, S. Bai, and W. Huang, "Adaptation of a conventional flipped course to an online flipped format during the COVID-19 pandemic: Student learning performance and engagement," *J. Res. Technol. Educ.*, vol. 54, no. 2, pp. 281–301, Mar. 2022.

[119] A. M. Njeru, "The effect of the flipped learning model on student achievement in a secondary. School mathematics classroom: A quantitative study," Ph.D. thesis, School Educ., Northcentral Univ., San Diego, CA, USA, 2020.

[120] S. R. Kuiper, R. H. Carver, M. A. Posner, and M. G. Everson, "Four perspectives on flipping the statistics classroom: Changing pedagogy to enhance student-centered learning," *PRIMUS*, vol. 25, no. 8, pp. 655–682, Sep. 2015.

[121] Z. Alias, M. Z. M. Hussin, N. A. Badruldin, and H. Taha, "The effectiveness of flipped classroom method on achievement and readiness in sets topic for form 4 students," *J. Sci. Math. Lett.*, vol. 9, no. 2, pp. 62–74, 2021.

[122] Y. Janatin, R. W. Y. Putra, and A. Hamid, "Upaya meningkatkan kemampuan pemahaman konsep matematis siswa SMP dengan menggunakan pembelajaran model flipped classroom," *Prosiding Seminar Nasional Matematika Pendidikan Matematika*, vol. 2, no. 1, pp. 125–139, 2019.

[123] X. Thaqi, J. Gimenez, and E. Aljimi, "The meaning of isometries as function of a set of points and the process of understanding of geometric transformation," in *Proc. 9th Congr. Eur. Soc. Res. Math. Educ. (CERME)*, 2015, pp. 591–597.

[124] A. H. Abdullah, *Pendidikan Matematik Menengah di Malaysia dan Korea Selatan*. Johor Bahru, Malaysia: Universiti Teknologi Malaysia, 2022.

[125] E. Kamaruddin, E. Sulaeman, L. Nurita, and L. D. Ningtyas, "Implementation of moodle e-learning in Mathematics," *IOP Conf. Ser., Mater. Sci. Eng.*, vol. 1098, no. 2, 2021, Art. no. 022098.

[126] C. K. Lo, K. L. Cheung, H. R. Chan, and C. L. E. Chau, "Developing flipped learning resources to support secondary school mathematics teaching during the COVID-19 pandemic," *Interact. Learn. Environ.*, pp. 1–19, Sep. 2021.

[127] I. Blau and T. Shamir-Inbal, "Digital competences and long-term ICT integration in school culture: The perspective of elementary school leaders," *Educ. Inf. Technol.*, vol. 22, no. 3, pp. 769–787, May 2017.

[128] N. K. Nida, B. Usodo, and D. R. S. Saputro, "Effectiveness of the flipped classroom model on the students' mathematical creative thinking skills," in *Proc. Int. Conf. Online Blended Learn.*, in Advances in Social Science, Education and Humanities Research, vol. 440, 2020, pp. 107–110.

[129] Y. Song, "How to flip the classroom in school students' mathematics learning: Bridging in- and out-of-class activities via innovative strategies," *Technol., Pedagogy Educ.*, vol. 29, no. 3, pp. 327–345, May 2020.

[130] M. A. N. Elmaadaway, "The effects of a flipped classroom approach on class engagement and skill performance in a blackboard course," *Brit. J. Educ. Technol.*, vol. 49, no. 3, pp. 479–491, May 2018.

[131] S. Hadi, H. Retnawati, S. Munadi, E. Apino, and N. F. Wulandari, "The difficulties of high school students in solving higher-order thinking skills problems," *Problems Educ. 21st Century*, vol. 76, no. 4, pp. 520–532, Aug. 2018.

[132] A. H. Abdullah, M. Mokhtar, N. D. Abd Halim, D. F. Ali, L. M. Tahir, and U. H. A. Kohar, "Mathematics teachers' level of knowledge and practice on the implementation of higher-order thinking skills (HOTS)," *EURASIA J. Math., Sci. Technol. Educ.*, vol. 13, no. 1, pp. 3–17, Oct. 2016.

[133] S. Otten, Z. de Araujo, M. Sherman, and S. Birişçi, "A framework for capturing structural variation in flipped mathematics instruction," *Int. J. Math. Educ. Sci. Technol.*, no. 11, pp. 1–32, Aug. 2021.

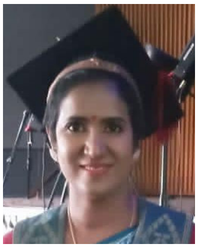
[134] K. F. Hew and C. K. Lo, "Comparing video styles and study strategies during video-recorded lectures: Effects on secondary school mathematics students' preference and learning," *Interact. Learn. Environ.*, vol. 28, no. 7, pp. 847–864, Oct. 2020.

[135] A. H. Abdullah and B. Shin, "A comparative study of quadrilaterals topic content in mathematics textbooks between Malaysia and South Korea," *J. Math. Educ.*, vol. 10, no. 3, pp. 315–340, Aug. 2019.

[136] M. Çevikbaş and Z. Argün, "An innovative learning model in digital age: Flipped classroom," *J. Educ. Train. Stud.*, vol. 5, no. 11, pp. 189–200, 2017.

[137] C. K. Lo and K. F. Hew, "A critical review of flipped classroom challenges in K-12 education: Possible solutions and recommendations for future research," *Res. Pract. Technol. Enhanced Learn.*, vol. 12, no. 1, pp. 1–22, Dec. 2017.

[138] A. M. Al-Zahrani, "From passive to active: The impact of the flipped classroom through social learning platforms on higher education students' creative thinking," *Brit. J. Educ. Technol.*, vol. 46, no. 6, pp. 1133–1148, Nov. 2015.



KALAIARASI NADARAJAN received the master's degree in mathematics education from Universiti Teknologi Malaysia (UTM).

ABDUL HALIM ABDULLAH (Member, IEEE) received the B.Sc. (Edu.) and M.Sc. (Edu.) degrees in mathematics education from Universiti Teknologi Malaysia (UTM), and the Ph.D. degree in mathematics education from Universiti Kebangsaan Malaysia (UKM). He has been working with the Faculty of Social Sciences and Humanities, School of Education, UTM, since 2006. He was also involved as a Researcher at the collaborative IRU-MRUN Research between Malaysian Research Universities and Australian Innovative Research Universities. He has received ten research grants as a Principal Investigator, including one from Majlis Amanah Rakyat (MARA), and 20 grants as a Co-Investigator. His research interests include geometry thinking, higher order thinking skills (HOTS) in mathematics, technology-aided teaching, and learning in mathematics.

NAJUA SYUHADA AHMAD ALHASSORA received the Ph.D. degree from Universiti Teknologi Malaysia (UTM). She is currently a Senior Lecturer with the Faculty of Social Sciences and Humanities, School of Education, UTM.

NOR HASNIZA IBRAHIM (Member, IEEE) is currently an Associate Professor with the Faculty of Social Sciences and Humanities, School of Education, Universiti Teknologi Malaysia (UTM). Her research interests include qualitative research, science, technology, engineering, and mathematics (STEM), and chemistry education.

JOHARI SURIF (Member, IEEE) is currently an Associate Professor with the School of Education, Universiti Teknologi Malaysia (UTM). His research interests include qualitative research, science, technology, engineering, and mathematics (STEM), and chemistry education.

DAYANA FARZEEHA ALI received the bachelor's and Ph.D. degrees from Universiti Teknologi Malaysia (UTM). She is currently an Associate Professor with the Faculty of Social Sciences and Humanities, School of Education, UTM. Her research interests include visualization skills and technical and vocational education and training.

NORASYKIN MOHD ZAID received the Bachelor of Science degree (Hons.) in computer science and the master's degree in educational technology from Universiti Teknologi Malaysia (UTM), Malaysia, in 2000 and 2006, respectively, and the Ph.D. degree from the University of Wollongong (UoW), Australia, in 2013. Since 2018, she has been the Program Coordinator of the Educational Technology Program for Postgraduate Studies. She is currently a Senior Lecturer at the Faculty of Social Sciences and Humanities, School of Education, UTM. Her research interests include online education and training, information systems, and new media in teaching and learning.

MOHD HILMI HAMZAH received the Ph.D. degree in phonetics from the University of Melbourne, Australia. He is currently an Associate Professor with the School of Languages, Civilisation and Philosophy, Universiti Utara Malaysia (UUM), Kedah, Malaysia. His research interests include phonetics and phonology, applied linguistics, and speech science and technology.

• • •