香港教育大學
The Education University of Hong Kong

MTH4902 Honours Project II (2022-23)

The Effectiveness of Using GeoGebra to Teach 2D and 3D Figures

Submitted by

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April 2023

Declaration

I, Yiu Chun Ngo declare that this piece of research is fully conducted on my own der the supervision of Mr. Mau Yuk Lun, the Lecturer II at The Education University of Hong Kong. The research report has not submitted previously in any one of the tertiary institutions.

Signature

7th April 2023

Content

Introduction

According to Curriculum Development Council (2017), Two-dimensional and three-dimensional graphics have been incorporated into the unit of study of Junior Secondary Mathematics. Most of the textbooks in Hong Kong had set up the unit of study as Areas and Volumes. Before learning this topic, teachers needed students to recognize its difference and graphics concepts (BYJU'S. n.d.). Students needed to have a distinct concept of the area was defined for 2-dimensional objects, and volume was defined as a 3-dimensional object. The curriculum has been separated into three stages for students to learn (HKUGA, n.d.). The requirement for beginners was learning how to find the areas of simple polygons, the volumes, and the total surface area of cubes and prisms. The next stage for students that need to understand the concept of circle, sector, and cylinder is to find their areas and volumes. Their final stage was finding the areas and volumes of pyramids, spheres, and circular cones. Moreover, students needed to learn to depict the flat image of a three-dimensional figure.

In the past few years, since the affection of the epidemic, many schools have switched teaching mode to online, causing teaching complications (McQueen, 2022). Teachers and students could only conduct lessons through online software—for example, Zoom, Webex, and Microsoft Teams. To adapt to the pandemic, e-learning has become a standard mode of teaching (Manou et al., 2022). In Mathematics lessons, online software – GeoGebra could be used as one of the recommended software for learning mathematics, remarkably demonstrating, or visualizing mathematical concepts and a tool for building mathematical concepts (Tamam & Dasari, 2021). It was beneficial for students to learn Mathematics during the pandemic.

Besides, the figures in the books were mostly fixed, and students could only observe in one way. Thus, teachers use GeoGebra for teaching, especially on Areas and Volumes, which could allow students to observe the figure from multiple perspectives. Therefore, students would better understand distinct 2D or 3D shapes. In response to recent educational trends, the application of GeoGebra in Two-dimensional and Three-dimensional Graphics to Mathematics education in Hong Kong will be explored below. The objectives are finding students' learning difficulties when learning 2D and 3D Figures and how using GeoGebra improves students' performance in understanding 2D and 3D Figures and their correlation.

Literature Review

Learning Difficulties in Shape and Space

Students needed help solving mathematics problems. Mazzocco et al. (2013) divided students' mathematical difficulties into two categories: mathematical dyscalculia and mathematical reasoning disorder. Students’ poor performance in problem-solving was mainly due to the abstraction of mathematics (Mitchelmore & White, 2004), insufficient use of teaching tools and modern technology (Odogwu, 2011), and lack of understanding of mathematical concepts (Ebisine, 2010), and so on. Dada et al. (2021) indicated that students need a higher level of understanding of measurement, which was one of the problematic content areas for them to learn. It was suggested that mathematics teachers should pay attention to the construction of concepts and guide students to generate formulas by themselves during the teaching process.

Musa and Bolaji (2015) defined the science of measurement as a numerical representation of geometric size, which could be linear measurements such as length, area, and volume measurements. It was critical in measurement since most objects dealing with humans had some shape with an area or volume. However, students and teachers had difficulties teaching and learning in this field. Udousoro (2011) analyzed that mensuration was one of the mathematics topics that students felt arduous, and the results showed that around 70% of students had determined that learning mensuration was difficult by Students' perception of mathematics complex concept questionnaire. Zimbabwe Schools Examinations Council (2010) commented that candidates had to handle three-dimension solid shape measurement. However, the performance was low. Besides, for teachers, Idehen (2012) indicated that teachers needed clarification about the difference between cubes and cuboids and needed help understanding the best description of a three-dimension shape, which led to wrong solutions in geometry problems. Moreover, Students felt formidable in measurement with understanding its concepts, and no significant progress was made over a long period (Salman, 2004). Research by Ekwue and Umukoro (2011) affirmed that many high school mathematics teachers should have taught specific topics, including logical reasoning and solid-like volumes since they thought those topics were hard to teach.

According to Ismail, et al. (2020), students could not state the characteristics of 2D and 3D shapes, and about 20% needed to comprehend how to draw those shapes. Some Secondary students could not use 2D shapes to externalize 3D objects (Gorgorió, 1998). Mofolo-Mbokane, et al. (2013) encouraged the representation of 2D and 3D shapes needed to enhance visualization skills. Aysen (2012) indicated that many students got the misconception about geometry since they were taking notes during the lesson, which caused excess cognitive load and negatively impacted student learning.

Effect of Using GeoGebra

Joshi (2020) pointed out that technology could change student-centered learning by empowering students to master learning methods, making education relevant to their digital lives, and preparing them for their future. Ramey (2013) claimed that using technology in education could extend the educational boundaries to infinity, which allowed a lesson to contribute in real-time using progressive educational technology. Using app software during mathematics lessons enabled teachers and students to build awareness of mathematical concepts (Joshi, 2020). In addition, Chalaune (2019) expressed that using GeoGebra in mathematics teaching and learning could simplify comprehension among students.

Chris (2007) discovered that GeoGebra could immediately generate mathematically accurate diagrams for questions. It admirably did what it was supposed to and had practical applications in teaching mathematics in higher education for many topics. For instance, school geometry and algebra tools for simple illustrations in mathematics. GeoGebra is an excellent tool for teaching linear equations and positively impacts students' expression of the linear equation (Joshi & Singh, 2013). Chalaune and Subedi (2020) stated that teachers using GeoGebra in mathematics lessons could strengthen students' behavior instead of traditional methods. It could reinforce the curiosity about the content especially 2D and 3D shapes, which could expound its concept.

Zulnaidi & Zakaria (2012) determined the impact of GeoGebra on functional concepts and procedural knowledge, which provides teachers the opportunity of teaching mathematics by using GeoGebra software. Research by Acharya (2015) revealed that students who used GeoGebra software did better in mathematics than those who did not. Students had a positive attitude toward using GeoGebra in their mathematics learning. Moreover, students enhanced their scores using Geogebra (Martinez, 2017). Besides, students were willing to use GeoGebra when learning Geometry, and the cognition of Geometry students increased (Gajurel, 2018; Kandel, 2018). In addition, Thanet (2019) analyzed that it was a useful app for teaching mensuration and construction. Furthermore, Joshi (2020) discerned that students actively used GeoGebra when learning mensuration and were more motivated to participate in teaching activities. Students supported using GeoGebra for learning geometry and thought it would be productive.

Mainali and Key (2013) concluded that using GeoGebra software helps to provide conceptual knowledge to students. Teachers indicated that GeoGebra helped provide conceptual and procedural knowledge. GeoGebra is widely believed to facilitate meaningful learning, provide practical math concepts, and enhance long-term memory of math concepts.

Correlation of GeoGebra and 2D, 3D Figures

Bhagat and Chang (2015) discovered that teachers used GeoGebra to teach geometry concepts, which examined that GeoGebra is an effective tool for teaching and learning geometry. Based on research, GeoGebra is an effective tool for improving comprehension and education in 2-dimensional geometry. Baloglu and Dogan's (2014) found that using GeoGebra was more beneficial than traditional teaching methods for senior form students. They used GeoGebra to demonstrate a superior understanding of concepts, improved problem-solving abilities, and greater motivation. Akgül (2014) research also revealed that GeoGebra improved visual learning and understanding of 2-dimensional geometry for junior-form students.

With the current development of technology, many applications can be used for teachers to use in mathematics teaching, and it is conventional to use GeoGebra to teach pyramids and prisms. Mathematics teachers, who use GeoGebra in geometry lessons, students performed better on space and shape than in traditional learning (Pamungkas, et al., 2020). Dogruer & Akyuz (2020) observed that using GeoGebra as a teaching tool supports students' conceptual understanding of three-dimensional shapes. GeoGebra enabled students to memorize its properties and solved the problems of students who were hard to observe on books and papers.

Additionally, GeoGebra has effectively improved comprehension and education of 3-dimensional geometry. Putra, Hermita, Alim, & Hidayat (2021) explored that GeoGebra was an effective method for teaching 3-dimensional geometry to high school students. The paper demonstrated that GeoGebra facilitated the development of better comprehension of 3D Figures and their properties among students while also improving their ability of visualization and manipulation.

Research Question

1. To explore the reasons for students' learning difficulties in 2D and 3D figures.

2. To analyze whether applying GeoGebra can improve students' performance.

The relationship between the topic and research questions is to discover the learning difficulties of students while learning 2D and 3D figures first by examining the teaching tools or methods in teaching during the lessons, whether it is effective or not, and next, by using the application of GeoGebra during the lesson with teaching 2D and 3D figures to let students observe each shape more comprehensively. After integrating GeoGebra and teaching 2D and 3D figures, the effectiveness will be exerted. The benefits and detriments will be analyzed below.

Methodology

Students have learned the mensuration, shape, and space of cubes and cuboids in Secondary 1, and they have learned to measure 2-D Figures and make 2-D and 3-D figures with the given information in the senior primary stage (Curriculum Development Council, 2017). Participants will be invited with this prior knowledge to participate in the study.

This research is conducted in both qualitative and quantitative research. Primary sources and data will be primary sources and data for data collection, video recording, students' work in worksheets, GeoGebra, pre-test, and post-test. Tests will be used for questioning students learning of Measure, Shape, and Space before and after using the applications of GeoGebra to observe students' motivation.

For qualitative data, the whole lesson will be video recorded. Through the class, observation is supposed to determine the difficulty and how participants respond in 'The effectiveness of using GeoGebra to Teach Measure, Shape, and Space.' Their working progress and findings will be recorded in class worksheets serving as written and video records.

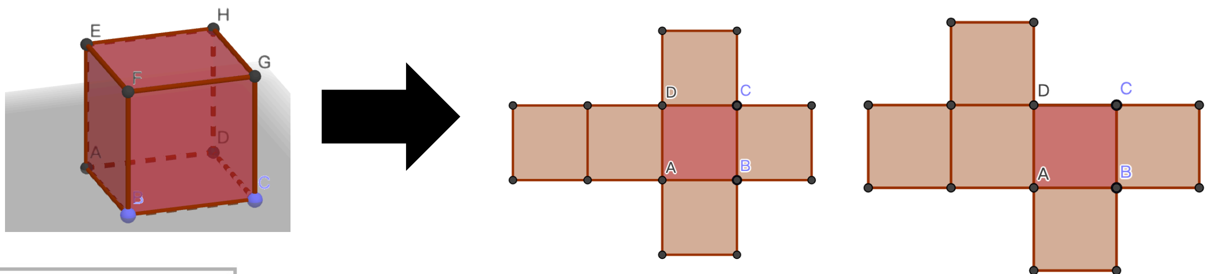
Second, both pre-test and post-test (see Appendix 1) for students about the knowledge of 2D and 3D shapes using GeoGebra before and after as quantitative data. To enhance the reliability, both tests will be conducted under the supervision of researchers, and face-to-face lessons will be limited to 15 minutes. The number of correct answers will be used to examine students' strengths and weaknesses in studying this topic. The tests will be divided into three parts. The first part examines students' understanding of the base, height, lateral face, and lateral edge of a prism, in which students can understand the forming of a prism with several numbers of edges, vertex, and faces (question 1). The second part examines students' understanding of the variation of dimension and length, which is the sense of space (questions 2 – 3 & 6). The third part examines students' understanding of the net of a prism. For instance, some nets of prisms are given, and students can determine their base and height. Next, students can understand finding the coincide with several vertexes if the net is folded into a prism. Moreover, students can comprehend how to find the opposite face of a letter after the net is folded into a prism (questions 4, 5 & 7).

The research is designed to pre-test during a face-to-face lesson, followed by a 30 – 40-minute exploration with an in-class worksheet (see Appendix 2). In the end, a post-test will be done to examine the effectiveness of using GeoGebra to teach 2D and 3D Figures.

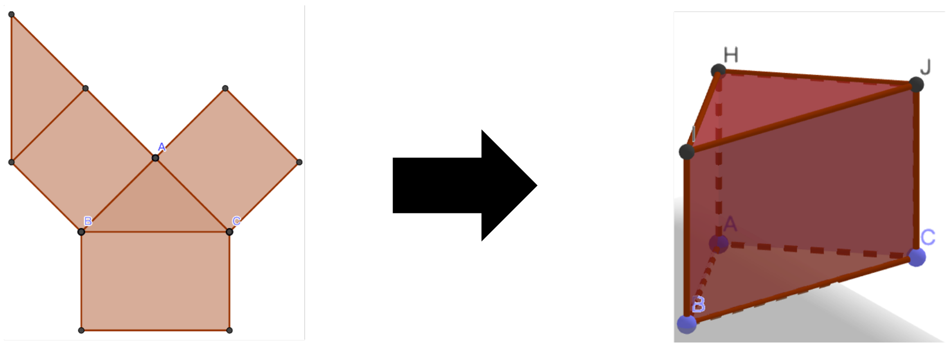
Research Design

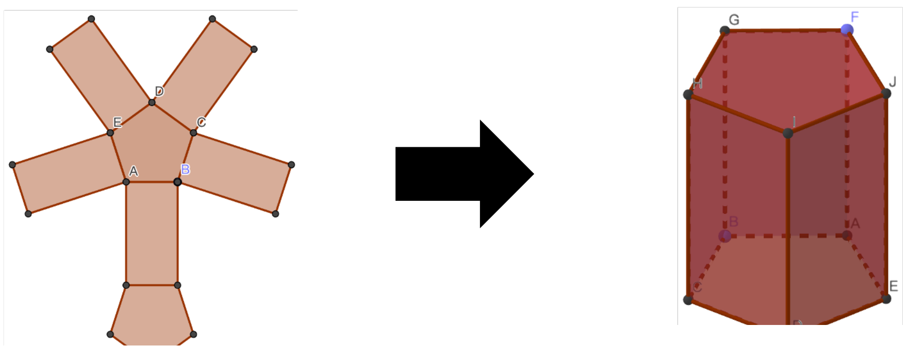
Firstly, some prior knowledge will be revised during the exploration. Students need to distinguish and write down those several right prisms. Next, students must distinguish a prism's base, lateral edge, and vertex. A cube will be provided, which is the clearest to show it for students to recognize. In this part, two more questions for students will be given. One is given several numbers of vertex, lateral edge, and face to think about its right prism. The other question is given the name of a right prism, then write down its numbers of vertex, lateral edge, and face. This part aims to give students the ability to imagine the shape of a three-dimensional figure and instructs students to try drawing the right prism in the blank area.

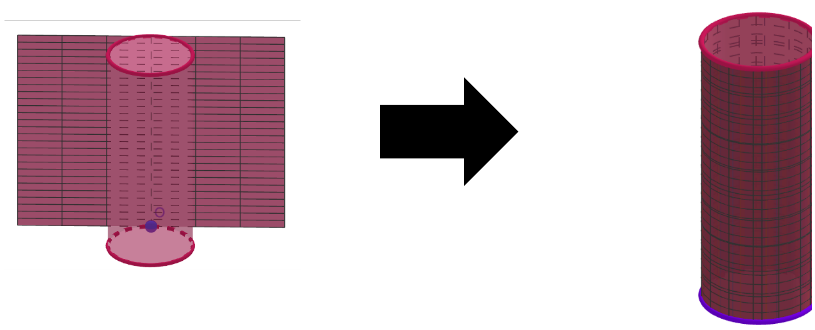
Secondly, GeoGebra Classic will be carried out during the exploration. During the process, some nets of a right prism will be shown. It starts from the elemental prism, the cube. Participants will sketch two of the nets of the cube by using a ruler. The researcher will keep observing participants' sketching. After that, the GeoGebra of 11 nets of a cube will be shown in both 2-D and 3-D graphics. The bars will be moved to demonstrate a different pattern of nets and the process of 2-D shape folding into a cube.



Next, some nets of right prisms will be given. Participants are required to fill in the blanks of each prism. For convenience, participants have been assisted in filling in the word "_____ prism" in the blanks. They need to recognize the shape of the base and understand that the lateral faces are parallelograms in a prism; they can just write down the shape of the base. Then, the GeoGebra of the net of a triangular prism, pentagonal prism, and cylinder will be shown in both 2-D and 3-D graphics. The bars will be moved to demonstrate the process of 2-D figures folding into a solid. It aims to concern the process of improving students' spatial imagination.

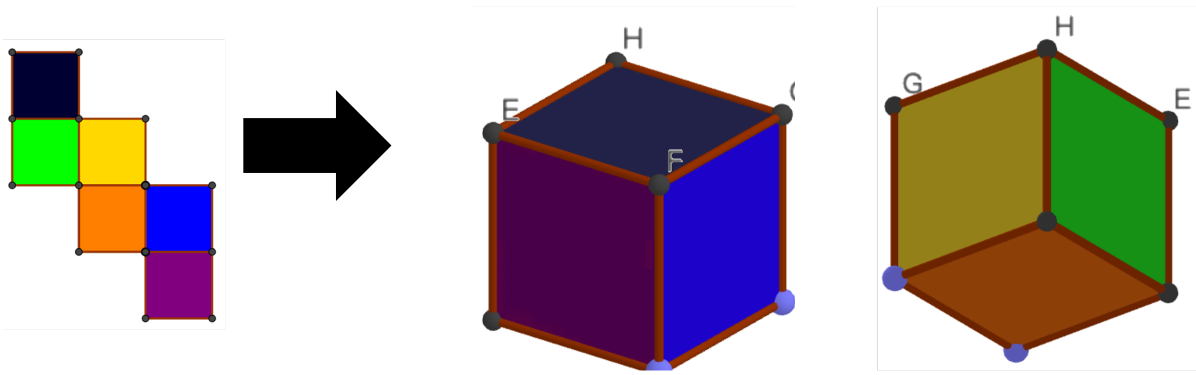




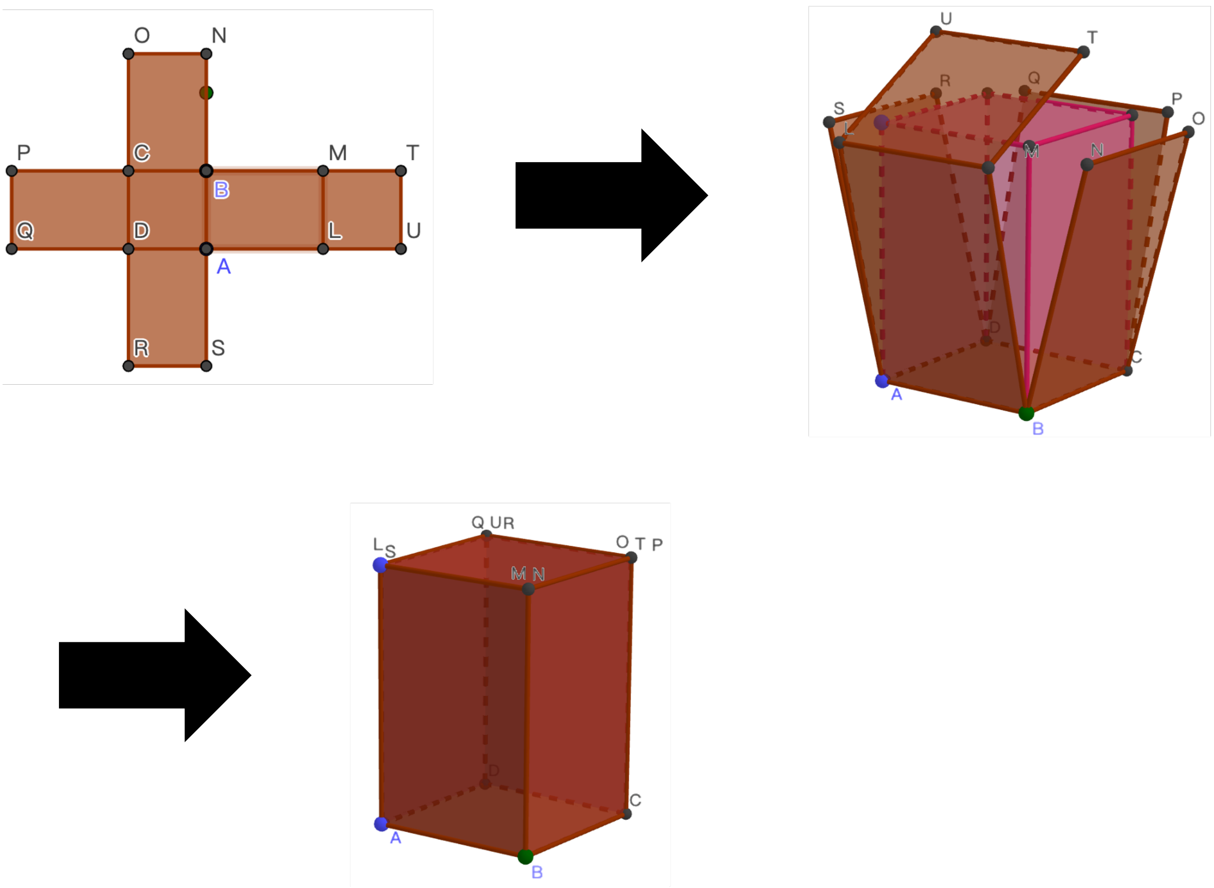


Indeed, the method of calculating the total surface area of a prism will be mentioned since they will learn the mensuration of the cylinder during the second stage of the junior secondary stage (Curriculum Development Council, 2017). The method will be used for participants to make them handier to do the operation.

In order to improve students' spatial imagination, a net of a cube will be given with several colors on each face. Participants are needed to imagine the prism of the net, then consider which color face is opposite to the other face. Moreover, the worksheet has designed a more difficult question as a challenge that asks which two faces are adjacent to the other face. Then, the GeoGebra of the net of the cube will be shown in both 2-D and 3-D graphics. The cube will be rotated so that participants can observe all the faces to find out which colors are opposite and adjacent to the other faces.



On the other hand, the net of a cuboid will be given, similar to the last question. Participants are required to imagine the fold to a cuboid with the vertex name given to find out which vertices and edges have coincided with another one. At last, the GeoGebra of the net of the cuboid will be shown in both 2-D and 3-D graphics. The cuboid will be folded slowly so that participants can observe clearly. It will focus on both the vertices and the edges that coincide.



Results

The result of the research is divided into three parts, respondents' understanding of prisms, variation of dimension, and net of a prism. The overall performance of the pre and post-test will be characterized, which was conducted with 51 participants to assess their understanding of geometric figures.

Result 1: The understanding of prism.

Question 1 in the pre-test and post-test examine students' performance on understanding prism.

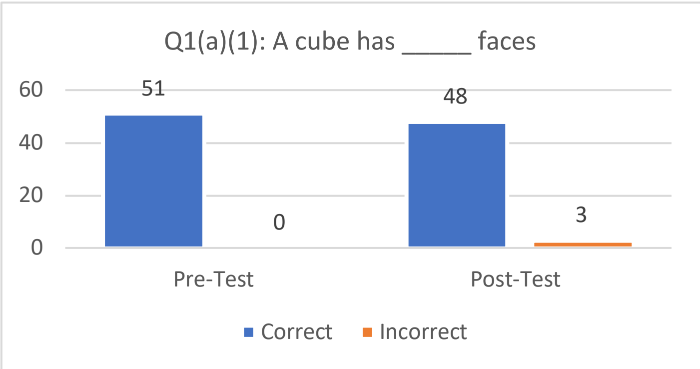
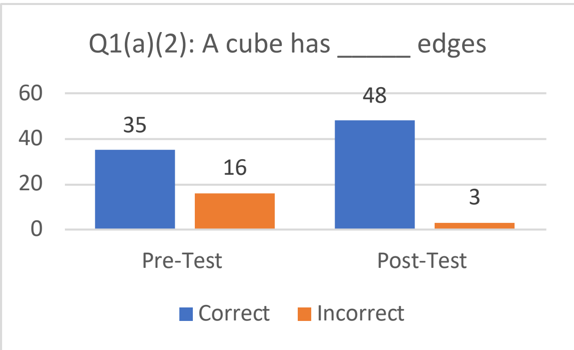


Figure 1: Respondents' comparison in question 1(a)(1) in pre-test and post-test



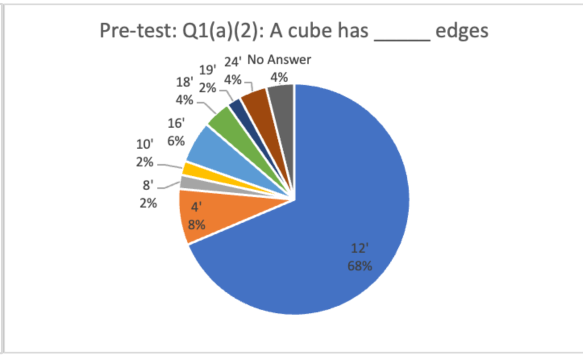
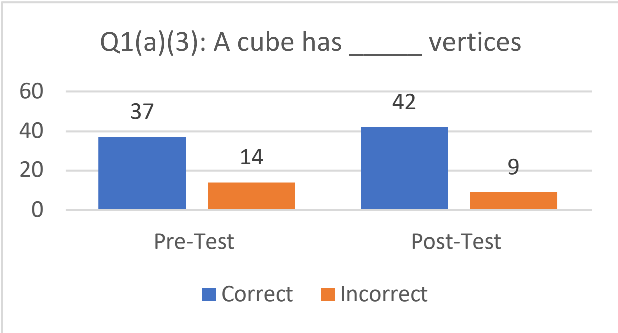


Figure 2: Respondents' comparison in question 1(a)(2) in pre-test and post-test

Figure 3: Respondents' distribution of answers in question 1(a)(2) in pre-test and post-test



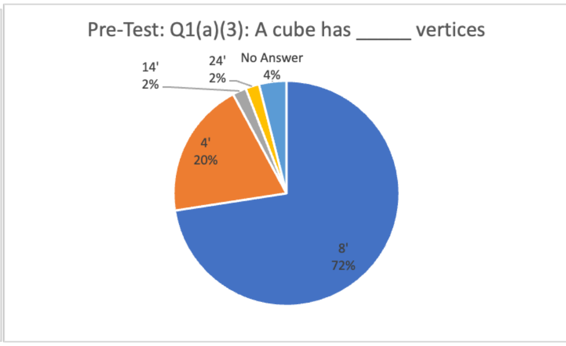


Figure 4: Respondents' comparison in question 1(a)(3) in pre-test and post-test

Figure 5: Respondents' distribution of answers in question 1(a)(3) in pre-test and post-test

Figures 1, 2, and 4 showed that all students answered correctly for the number of faces, while 100%, 68.6% and 72.5% of the students answered correctly for the number of edges and vertices, respectively in the pre-test. In the post-test, the percentage of correct responses increased for Q1(a)(2) and Q1(a)(3), with 94.1% of the students answering correctly for the number of edges and faces. According to Figure 3, it showed that 68% of students answered correctly on the number of edges, and from Figure 5, it indicated that 72% of students answered correctly on the number of vertices, and 20% of students answered '4'. The most significant improvement was observed for the question on the number of edges, with an increase of 25.5% in the percentage of correct responses.

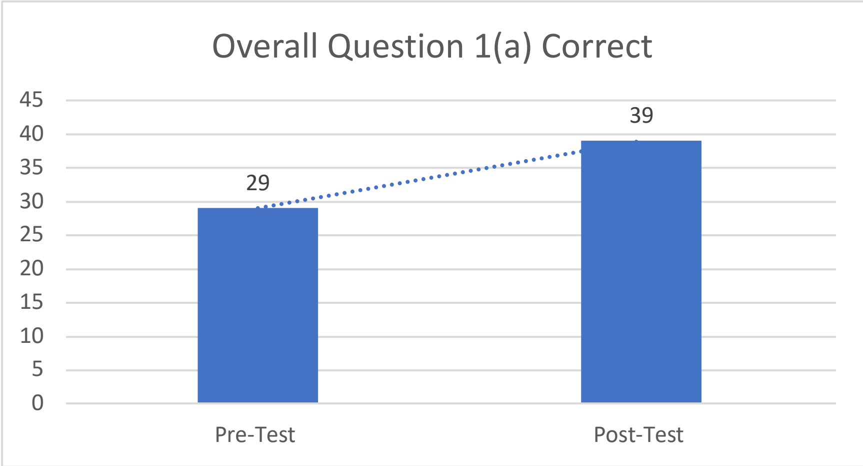


Figure 6: Respondents' distribution of answers in question 1(a) in pre-test and post-test

Figure 6 shows the performance of question 1(a) those students improved from the pre-test to the post-test. In the pre-test, only 29 out of 51 students, 56.9%, could correctly fill in all the blanks, while in the post-test, 39 out of 51 students, 76.5%, could do so. This represents an increase of 19.6% in the number of students who could correctly from the pre-test to the post-test.

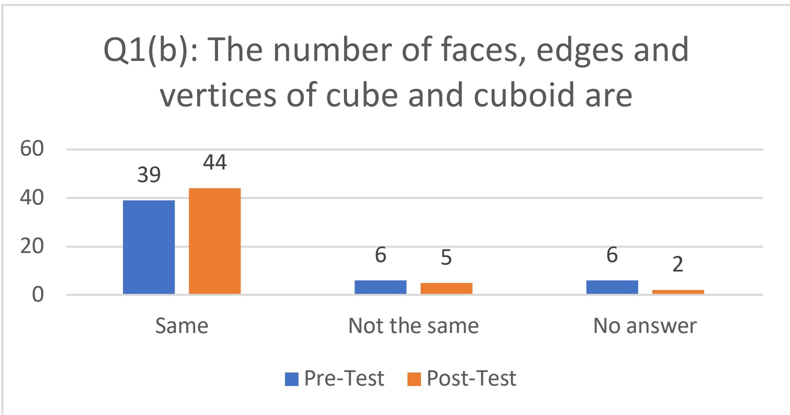


Figure 7: Respondents' distribution of answers in question 1(b) in pre-test and post-test

Figure 7 shows the results of question 1(b) that there was an improvement in the percentage of correct answers between the pre-test and post-test. In the pre-test, the average percentage of correct answers was 76.5%. The average percentage of correct answers in the post-test increased to 86.3%. On top of that, it showed that there were 5 more students answered correctly in the post-test and 4 more students at least tried to determine whether the numbers were the same. Thus, it showed a positive impact on students' understanding of the basic properties of a prism.

Result 2: The Understanding of Variation of Dimension

Questions 2, 3, and 6 in the pre-test and post-test examine students' understanding of the dimension variation.

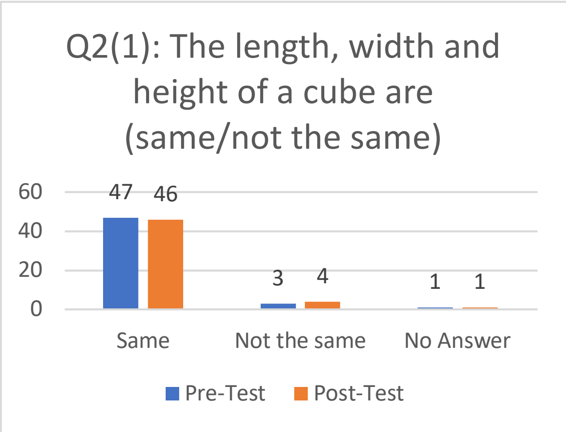


Figure 8: Respondents' distribution of question 2(1) in pre-test and post-test

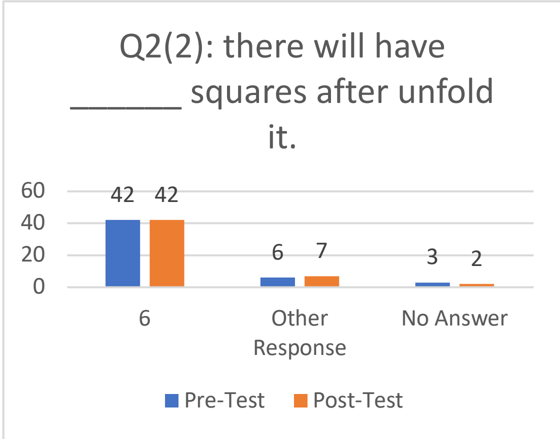


Figure 9: Respondents' distribution of answers in answers in question 2(2) in pre-test and post-test

According to Figures 8 & 9, in the pre-test, 47 students, 92.2%, answered that the length, width, and height of a cube are the same, while 42 students, 82.4%, answered that there are 6 squares after unfolding it. In the post-test, the result remained the same that 47 students, 92.2% still answered that a cube's length, width, and height are the same, while 43 students, 84.3%, answered that there are 6 squares after unfolding it. For other responses, only a few students answered that there was 1 square after unfolding it. Furthermore, in both pre-test and post-test, most students correctly answered that a cube's length, width, and height are the same. Most students correctly answered that there are 6 squares after unfolding a cube. There were a few responses in the post-test that needed to be corrected.

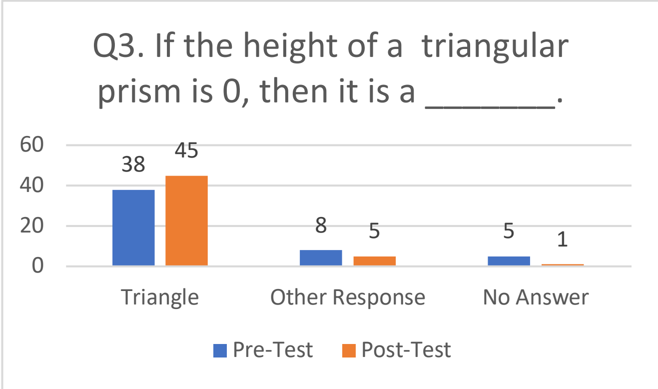


Figure 10: Respondents' distribution of answers in question 3 in pre-test and post-test

Figure 10 shows the result of question 3. In the pre-test, 38 students, 74.5%, correctly answered "triangle", while 8 students, 15.7%, gave other responses, and 5 students, 9.8% did not answer. In the post-test, 45 students, 88.2% correctly answered "triangle", while 5 students, 9.8% gave other responses, and only 1 of them, 2%, did not answer. The result has increased by 18.4%. However, for other responses, a few students answered 'circle' and 'quadrilateral'.

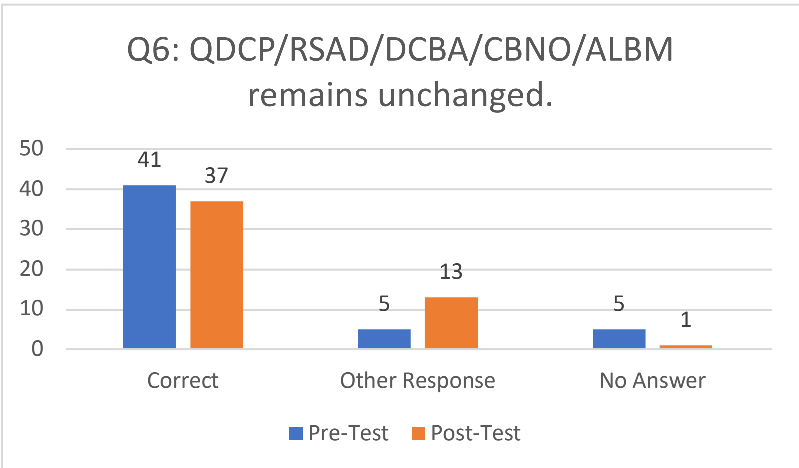


Figure 11: Respondents' distribution of answers in question 6 in pre-test and post-test

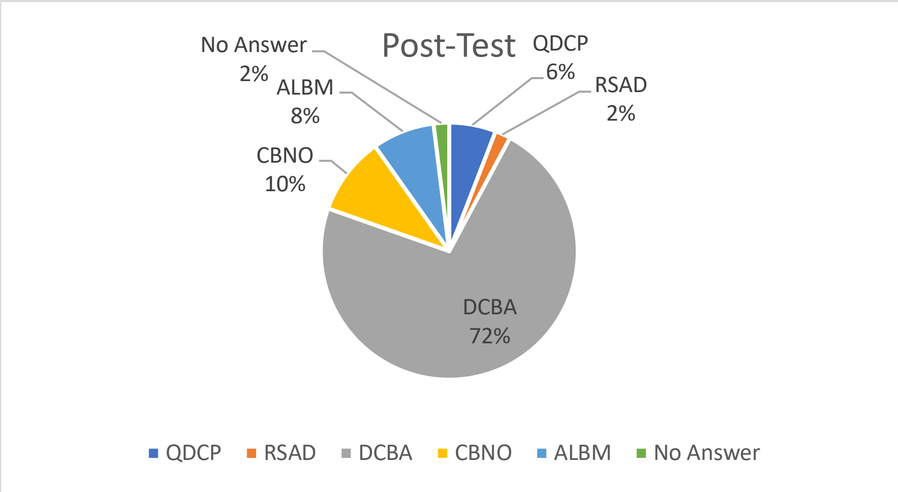


Figure 12: Respondents' distribution of answers in question 6 in post-test

The combined result of Figures 11 & 12 shows that the number of correct responses (DCBA) decreased slightly from 41 in the pre-test to 37 in the post-test. However, "other responses" increased from 5 in the pre-test to 13 in the post-test. The proportion of students who chose the correct answer also decreased slightly from 80.4% in the pre-test to 72.5% in the post-test, the decreased percentage was 9.76%, and 18% of students answered 'CBNO' and 'ALBM'. Thus, students may need clarification about which rectangle remains unchanged when the height of the cuboid is increased.

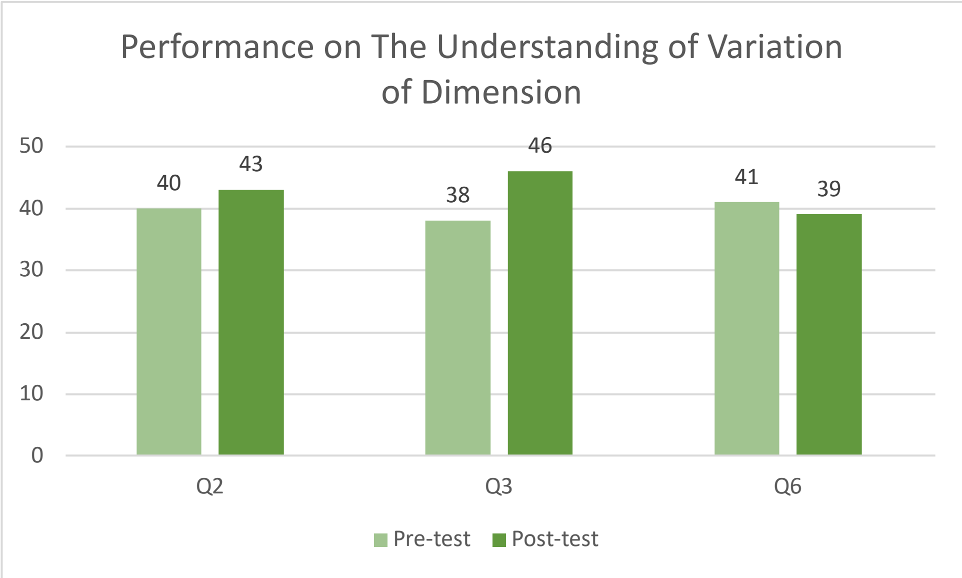


Figure 13: Respondent's Performance on The Understanding of Variation of Dimension

From Figure 13, Q2 and Q3 exhibited increased scores from the pre-test to the post-test 7.5% and 21% respectively, indicating a performance improvement. Yet, the lower score on Q6 on the post-test, slightly decreased by 4.9%.

Result 3: The Understanding of the Net of a Prism

Questions 4, 5, and 7 in the pre-test and post-test examine students' understanding of the net of a prism.

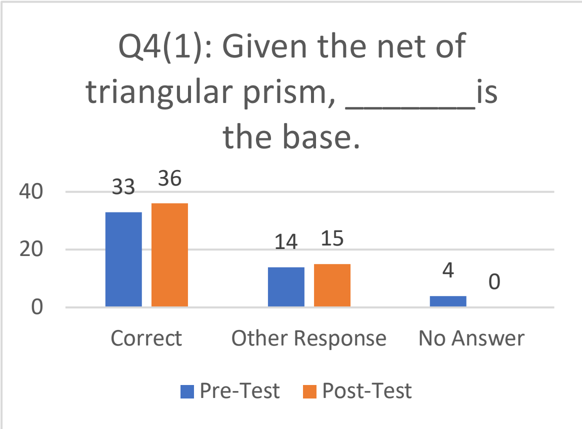


Figure 14: Respondents' distribution of answers in question 4(1) in pre-test and post-test

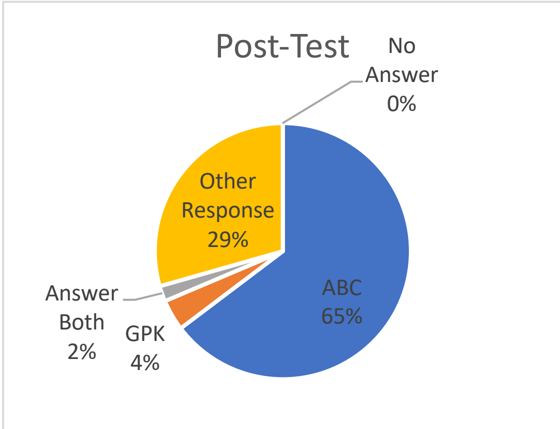


Figure 15: Respondents' distribution of answers in question 4(1) in post-test

According to Figures 14 &15 for Q4(1), the percentage of correct responses increased from 64.7% in the pre-test to 70.6% in the post-test, which showed an improvement after the GeoGebra lesson. The percentage of other responses also increased slightly from 27.5% in the pre-test to 29.4% in the post-test. The percentage of no responses decreased from 7.8% in the pre-test to 0% in the post-test, which showed that at least all the students tried to determine the base of a net of the triangular prism. In addition, 1 student can answer both 'ABC' and 'GPK' in the post-test (See Figure 16).

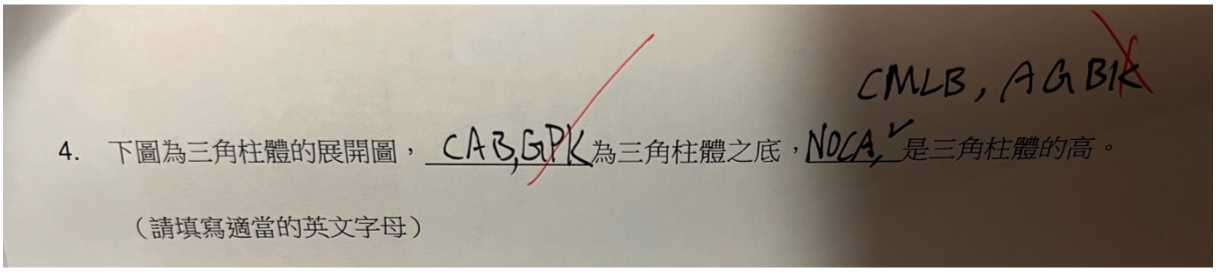


Figure 16: Respondent's Answer of Q4(1)

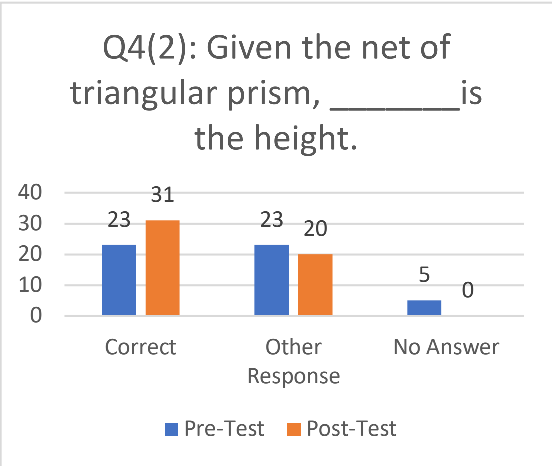


Figure 17: Respondents' distribution of

in question 4(2) in pre-test and post-test

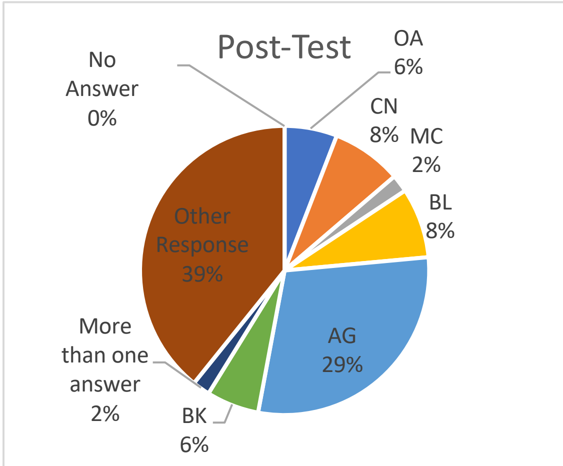


Figure 18: Respondents' distribution of answers

answers in question 4(2) in post-test

From Figure 17 for Q4(2), the percentage of correct responses increased from 45.1% in the pre-test to 60.8% in the post-test. The increased percentage was 34.8%. The percentage of other responses decreased from 45.1% in the pre-test to 39.2% in the post-test. The percentage of no responses decreased from 9.8% in the pre-test to 0% in the post-test. At that, Figure 18 shows the proportion of students for question 4(2) who answered 'AG' had a proportion of 29.4%. This specified that about 30% of the students correctly identified 'AG' as the height of the triangular prism, which significantly improved compared to the pre-test result. The second highest proportion answered 'CN' and 'BL', with 7.84%. The other answers, including 'OA', 'MC', and 'BK', each had a proportion of 5.88% or less, designating that only a small number of students answered. Indeed, there is one student who answered more than one answer, who answered correctly (See Figure 19).

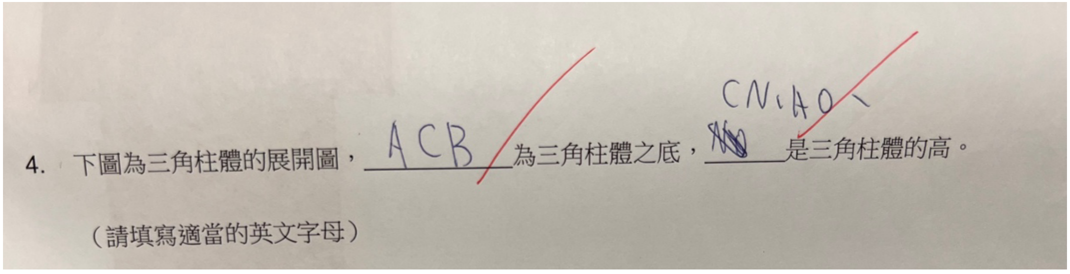


Figure 19: Respondent's Answer for Q4

In addition, 20 out of 51 students gave other response, for instance, ‘AB’, ‘AC’, indicating that they provided an answer that was the edges of the base triangle (See Figure 20& 21). This may prudent that some students needed help understanding the question or identifying the correct answer. Finally, it indicated that all students attempted to answer the question.

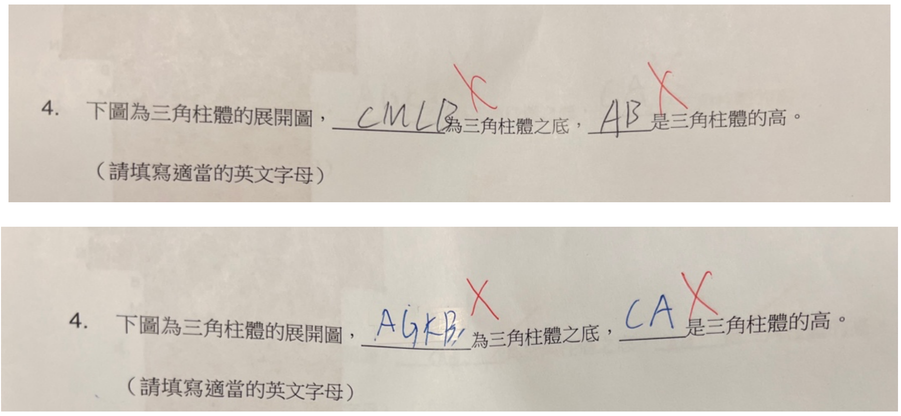


Figure 20 & 21: Respondent's Answer for Q4

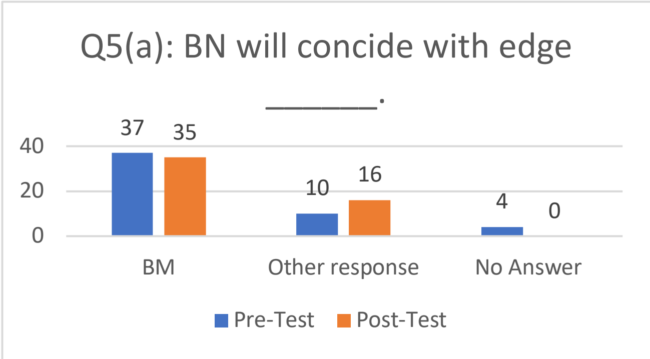


Figure 22: Respondents' distribution of answers in question 5(a) in pre-test and post test

From Figure 22 of question 5(a), the number of students who correctly answered "BM" decreased from 72.5% in the pre-test to 68.6% in the post-test. The decreased percentage was 5.4 %. The number of other responses increased from 19.6% in the pre-test to 31.4% in the post-test. The number of no responses decreased from 7.8% in the pre-test to 0% in the post-test. In the post-test, there were still 31.3% of students gave other responses, such as 'MN', 'SA', and 'CO'.

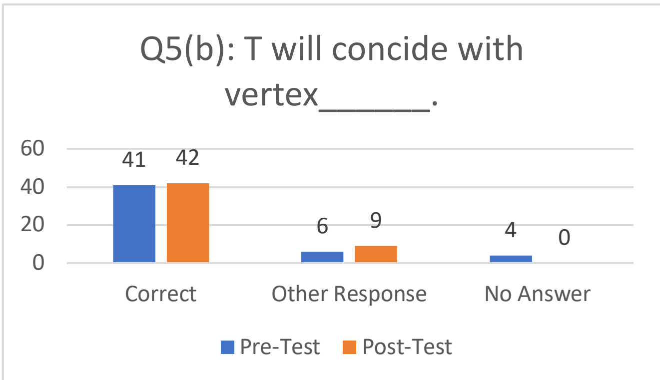


Figure 23: Respondents' distribution of answers in question 5(b) in pre-test and post test

Figure 23 showed that in the pre-test, 41 out of 51 students answered the question correctly, while 6 students gave other responses, and 4 students did not answer the question. Withal, in the post-test, 42 out of 49 students answered the question correctly, a slight improvement from the pre-test with the increased percentage of 2.4%. 9 students gave other responses, which increased from the pre-test, while none left the question unanswered. Based on these results, there was a slight improvement.

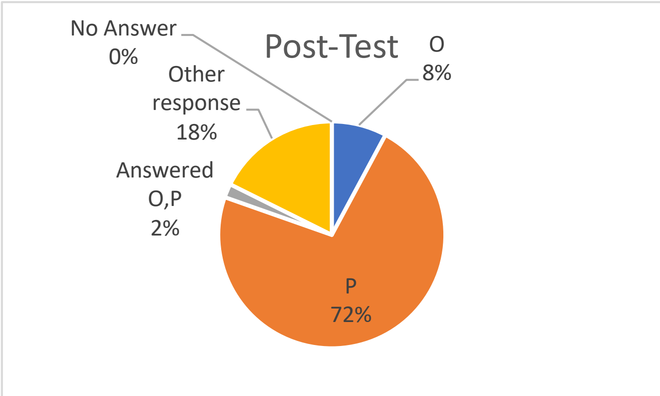


Figure 24: Respondents' distribution of answers in question 5(b) in post-test

To Figure 24, the percentage of correct responses for question 5(b) in the post-test was 80.4%, there were 72.5% of students who answered 'P' and 7.84% of students who answered 'O'. There was also 1 student who answered 'O/P' (see Figure 25), which can be interpreted as answering both O and P so that it could be counted as a correct response.

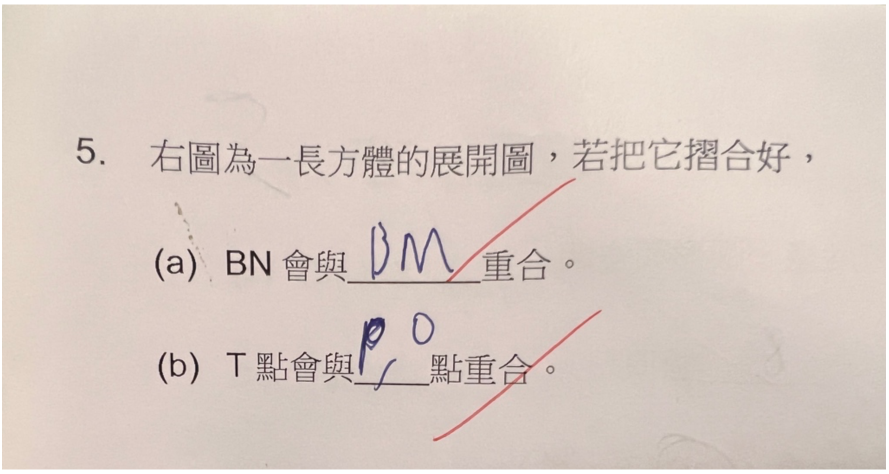
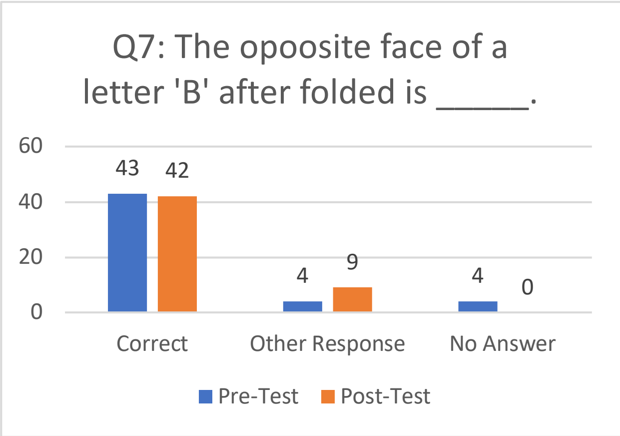


Figure 25: Respondents' answer in Q5(b)



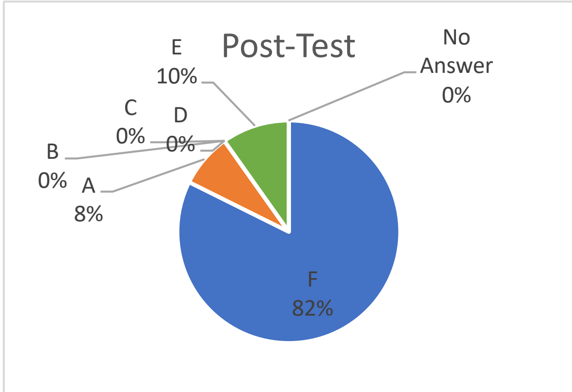


Figure 26: Respondents' distribution of answers in question 7 in pre-test and post-test

Figure 27: Respondents' distribution of answers in question 7 in post-test

In Figure 26 of question 7, the letter 'F' was the correct answer. In the pre-test, 84.3% of students answered correctly, while 7.8% of students gave another response, and also 7.8% of students did not answer the question. In the post-test, 42 out of 51 students answered correctly, slightly lower than the pre-test percentage, with the decreased percentage of 2.3%. 9 students gave another response, higher than the pre-test percentage, and none left the question unanswered. Besides, Figure 27 showed that more than 80% of students answered 'F', 7.84% of students answered 'A', and 9.80% of students answered 'E' in the post-test.

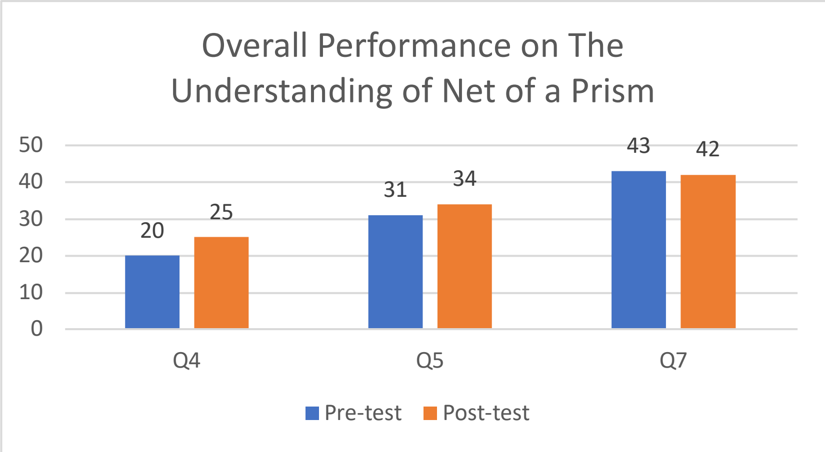


Figure 28: Respondents' distribution on pre-test and post-test on questions related to 'The Understanding of the Net of a Prism'

From Figure 28, the performance of all three questions for 'The Understanding of the Net of a Prism' that the results have improved. Based on the pre-test and post-test results, there was a slight improvement in the student's performance in questions 4, 5, and 7. In question 4, the number of correct responses increased from 20 in the pre-test to 25 in the post-test, which expressed a positive change (25%) in understanding. Similarly, in question 5, the number of correct responses increased from 31 in the pre-test to 34 in the post-test, indicating a slight improvement (9.67%) in student performance. For question 7, the number of correct responses decreased from 43 in the pre-test to 42 in the post-test, which is a minor deteriorate (2.38%).

The overall performance of respondents in the pre-test and post-test are shown in Figures 29, 30, and 31.

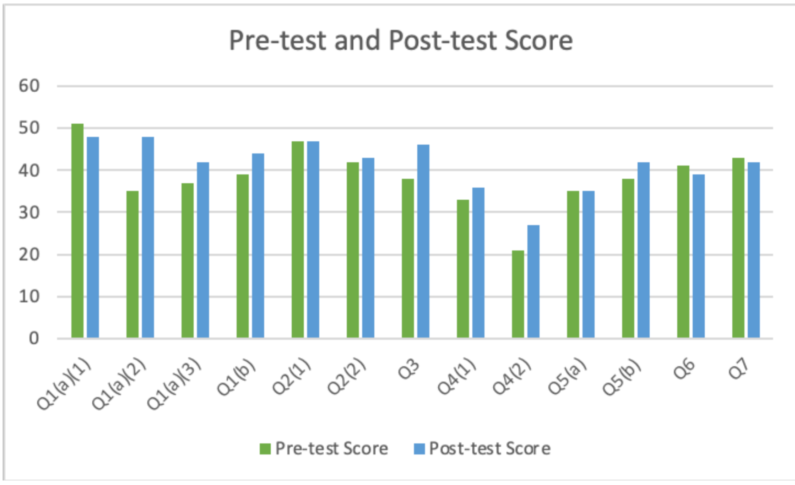


Figure 29: Respondents' performance comparison in pre-test and post-test

From Figure 29, it was the result comparison between pre-test and post-test. Among to 51 students, it had a roughly positive change in the post-test. While there were only 3 questions got slightly negative change, which are Q1(a)(1), Q6 and Q7. Meanwhile, Q1(a)(2), Q3 and Q4(2) demonstrated most significant changes.

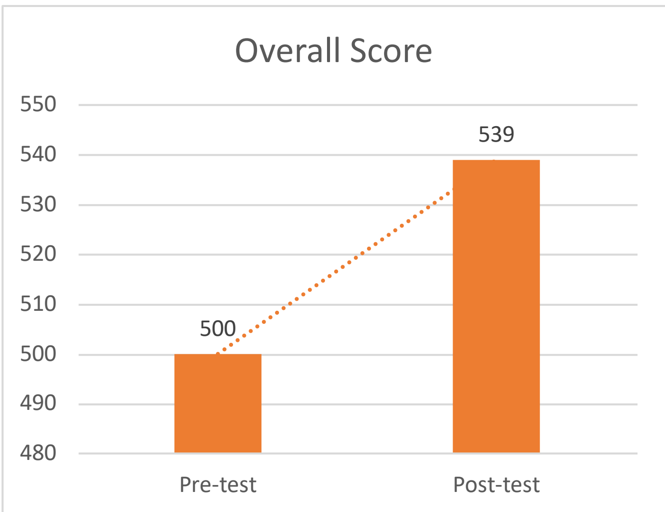


Figure 30: Respondents' distribution of overall performance in pre-test and post-test

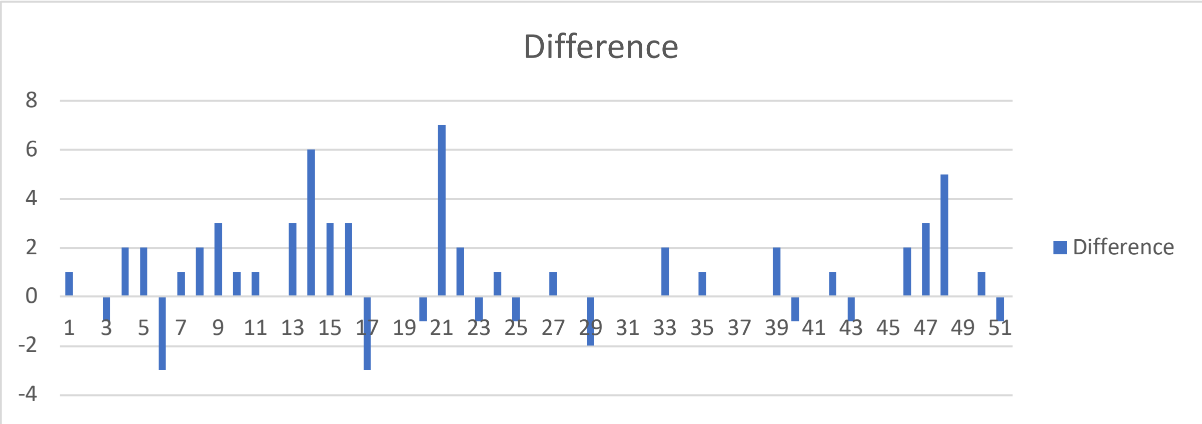


Figure 31: Respondents' score difference in pre-test and post-test on all questions

According to Figures 30, the overall performance increased by 7.8% and from Figure 21, there is a clear improvement in Q2(1), Q2(2), Q3, Q4(2), Q5(a), Q5(b), Q6, and Q7 between pre-test and post-test based on the increase in the percentage change. However, there is a decrease in performance in Q1(a)(1), Q4(1), and Q7. Into the bargain, in terms of the score difference between the pre-test and post-test in Figure 31, the majority of students showed improvement (23), followed by no difference (20), and a smaller number of students performed worse (8). In contrast, the results specified an improvement in the student's performance between the pre-test and post-test.

Discussion

In this part, respondents' results will be discussed, with the implications of findings and reflected on them, including the reason for learning difficulties with 2D and 3D figures; and how GeoGebra can improve student performance on this topic.

Discussion 1: The reason for learning difficulties on 2D and 3D figures

Based on the results of the pre-test and post-test, it was observed that students in both Class 2B and Class 2C have difficulties understanding certain concepts related to 2D and 3D Figures. Despite a slight increase in overall performance in the post-test, some students still needed help with specific questions, as evidenced by the number of students who showed no difference or even a decline in their scores.

One possible reason for this difficulty may be related to the teaching approach used in the classroom. While using GeoGebra software can be an effective tool in teaching Shape and Space, it is essential to ensure that students are fully engaged and focused on the software during the lesson. In Class 2C, for instance, some students appeared more interested in working independently than actively participating in the GeoGebra activity. In contrast, in Class 2B, students showed more focus on GeoGebra, which resulted in an improvement in their scores.

Another possible reason for the learning difficulties may be the complexity of the concepts covered in 2D and 3D Figures. According to Hiebert and Carpenter (1992), students often need help with geometry concepts due to their abstract nature and difficulty visualizing spatial relationships. Teachers should use various instructional strategies to help students understand these concepts, including practical manipulatives and visual aids (Clements & Sarama, 2009).

To sum up, while using GeoGebra software can effectively teach 2D and 3D Figures, it is vital to ensure that students are fully engaged and focused during the lesson. Teachers should also use various instructional strategies to help students comprehend intricate geometry concepts.

Discussion 2: How GeoGebra be able to improve students' performance on 2D and 3D Figures.

Based on the above results, in the first part, the study examines the understanding of prisms, asking respondents to identify the number of faces, edges, and vertices of cubes and cuboids. The results appeared that students' understanding of prisms has improved from the pre-test to the post-test, and the correct answer rate of the two questions on prisms and surfaces has increased. Still, from the perspective of the whole question 1(a), the percentage of correct answers has increased, especially the answer to the number question has been dramatically improved, and the percentage of correct answers to question 1(b) has also increased. This exhibited that students have a better understanding and positive impact on the fundamental properties of prisms after the GeoGebra lesson.

In the second part of the study, understanding of dimensional changes was assessed through questions related to the cube's length, width, and height and the number of squares when cube was unfolded. This concept involves how objects change size and shape while maintaining their characteristics, with a few similar concepts that help students understand changes in a three-dimensional shape. It was found that students with a strong understanding of dimensionality can solve more complex mathematical problems than those who do not (NCTM, 2000).

From the above results, most students answered correctly in both the pre-test and the post-test, expressing they understood the concept well. In this part, it was found that the student's scores did not improve significantly from the pre-test to the post-test, and there was only a slight decrease in one question. The percentage of correct responses for all three questions remained relatively stable. Though, it should be noted that the student's performance in the pre-test has been relatively high, and the correct answer rate of the three questions has exceeded 80%. This may manifest that students have a good understanding of the concept prior to taking the GeoGebra exploration.

The third part of the research aimed to assess participating students' understanding of Prism. A net is a 2D representation of a 3D object, and in the case of a prism, it is a pattern that can be folded to form a prism. Knowing how to read and interpret the net of a prism is crucial in many fields and it is essential to the fields in which students will be exposed to future opportunities, such as engineering, architecture, design, and so on. A pre-test assesses the student's basic understanding the net of a prism. Through classroom observation, some students' hands twisted continuously when answering this part of the question, which can be understood as imagining the figure of the three-dimensional figure at that time. Then after instruction and observation in GeoGebra of the evolution of the unfolded graph into a solid Figure, the students took a post-test to assess their understanding of the net of a prism after the exploration.

The results revealed that the percentage of correct answers increased from the pre-test to the post-test, indicating that students' understanding of the concept improved. This results in teaching and practice that effectively enhances students' knowledge and skills related to Prism.

To summarize, the results of this research expressed that the use of GeoGebra can improve students' understanding of 2D and 3D graphics, with 3D graphics being the most effective, providing students with an interactive learning experience and promoting a deeper understanding of the concept of two-dimensional to three-dimensional graphics, improve students' spatial imagination and abstract thinking.

For the difference between the GeoGebra class and regular class, using GeoGebra in math class has advantages over traditional class. GeoGebra accelerates interactivity and engagement by allowing students to manipulate graphics and change parameters. GeoGebra can create 2D and 3D graphics independently controlled through rotation and from different angles, teachers can assign students to learn after the lesson of Shape and Space, providing better visualization and a deeper understanding of dimensional relationships.

Limitations and Suggestions

The initial sample group consisted of Secondary 2 students from the practicum school in my neighborhood, who had a common educational background. They were told that prior knowledge could lead to similar responses to the questions, suggesting that their responses may only be representative of a small proportion of secondary school students in Hong Kong. To conduct similar studies in the future, expanding the pool of participants by including individuals from different educational backgrounds and increasing the sample size is recommended.

Additionally, a lot of time was spent solving technical challenges, including getting the GeoGebra to display correctly and troubleshooting network connectivity issues. For instance, scaling a cylinder in GeoGebra without moving the value slider, opening multiple prepared GeoGebra presentations upon entering a classroom, and setting up a classroom video, all presented challenges. Such problems require participants to wait 5-10 minutes, reducing teaching efficiency and affecting classroom order. Therefore, researchers are advised to make adequate preparations, such as contacting IT colleagues and practicing using tools in advance. More, using multiple teaching tools simultaneously, such as viewing researcher presentations and completing multi-page class worksheets, may overwhelm respondents. Therefore, minimizing the number of tools used or using tangible teaching tools instead is recommended.

As well, the number of questions on class worksheets can be reduced or replaced with oral questions since they represent only a tiny part of the exploration.

Practical questioning techniques can improve the quality of pre-test, post-test, and exploration. Nevertheless, students often need help understanding the questions, especially when the questions involve converting from 2D to 3D figures or when a lot of information is contained in a single question. To address this, it is recommended to break down the question into smaller subsections and provide hints for unfamiliar vocabulary. Researchers can also provide leading questions to help participants think. Furthermore, the problem statement should be more precise. For example, on question 4 of the pre-test, participants were not expected to provide answers such as "triangle" and "rectangle." Although relevant words have been added in the post-test and the situation has improved, in order to avoid harassing the participants in future studies, the researchers added instructions during the test: "Please fill in the corresponding English letters."

It should be noted that, filling in multiple answers may affect the analysis results. For instance, in question 4, participants provided multiple correct answers, but could still affect the analysis. And throughout, a particular finding emerged in questions 4 and 5(b), where some participants also provided two answers to a question, even though only one was required. To prevent this, it is advisable to include instructions such as "Only one letter of

English is required". Even so, it gives the impression that the students can see more after the GeoGebra class.

The paragraph discussed above (Discussion 1) demonstrates how students must acquire prior knowledge of shape and space, making interpreting figures associated with prisms challenging. It advises that instead of relying solely on formulas to calculate surface area or volume, teachers should ensure that each student is familiar with the basic properties of prisms, understand their shapes, and help students understand the basic concepts involved in interpreting shapes before teaching the lesson.

To boot, the current curriculum could add a chapter covering the expansion of prisms, cones, and pyramids to surface area. This additional material deepens students' understanding of concepts and helps them apply knowledge to more complex problems. By incorporating these changes, teachers can help students build a stronger foundation in 2D and 3D figures, enhance their ability to interpret graphics, and improve their performance in related subjects.

Conclusion

To sum up, this research examined the effectiveness of using GeoGebra to teach 2D and 3D graphics to Secondary 2 students in Hong Kong. Literature review concluded that GeoGebra is a versatile tool that could enhance students' understanding of mathematical concepts by providing visual and interactive representations. The research question explored whether using GeoGebra would improve the performance of the pre-test, post-test, and exploration.

To determine the changes from the pre-test to the post-test, the students appeared improvement, and some students' scores remained unchanged or declined. Thus, the results of the research expressed that even though students' performance in the pre-test and post-test has improved significantly, many factors still affect their performance. It is indeed difficult for students to improve their sense of space quickly. Research can be carried out for a long period.

Limitations of the research include the small sample size, homogeneity of the sample group, and technical difficulties in using GeoGebra. Recommendations for future research include expanding the participant pool, providing adequate preparation for participants and researchers, minimizing the number of teaching tools used, and improving questioning skills.

Besides, the research recommended that teachers focus on teaching the basic properties of prisms to help students grasp the basic concepts rather than relying entirely on formulas.

In conclusion, this research provided valuable insight into the advantages of using GeoGebra to teach 2D and 3D figures. Teachers can create a more engaging and effective learning environment by incorporating interactive and visual aids such as GeoGebra to enhance students' understanding of mathematical concepts.

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Appendix

Appendix 1: Pre-test and Post-test (2 pages)

班別：　　　　　　　　　　　　　　　　　　　　學號：

用 Geogebra 學習度量、圖形與空間

1. (a) 一個正方體有______個面，______條棱，______個頂點。

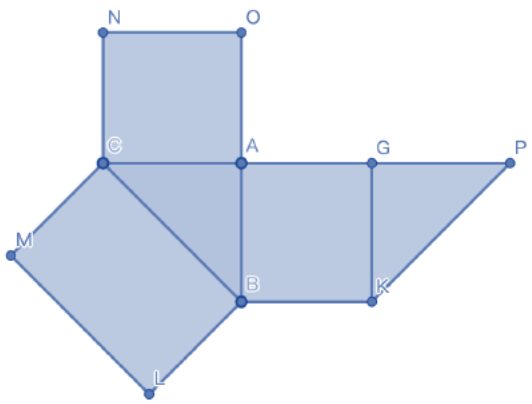
   (b) 長方體與正方體的頂點、棱、面的數量分別是（一樣/不一樣）。

2. 正方體的邊長、闊及高的長度均（相同/不相同），展開後會出現______個正方形。

3. 若三角柱體的高度為 0，那是一個_________形。

4. 下圖為三角柱體的展開圖，___________為三角柱體之底，______是三角柱體的高。

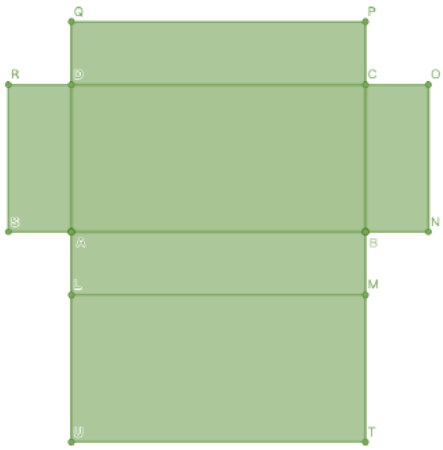
   （請填寫適當的英文字母）



5. 右圖為一長方體的展開圖，若把它摺合好，

(a) BN 會與________重合。

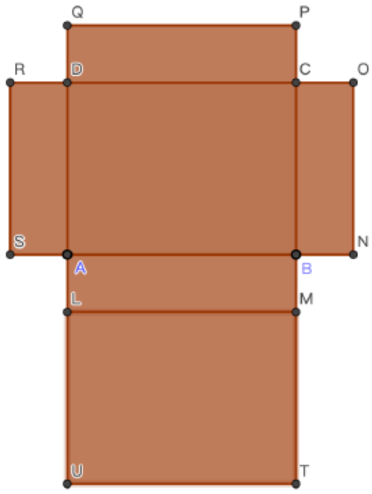
(b) T 點會與____點重合。



6. 右圖為一長方體的展開圖，以 LMTU 為底，若長方體的高增加，

（QDCP/RSAD/DCBA/CBNO/ALBM）不會出現變化。

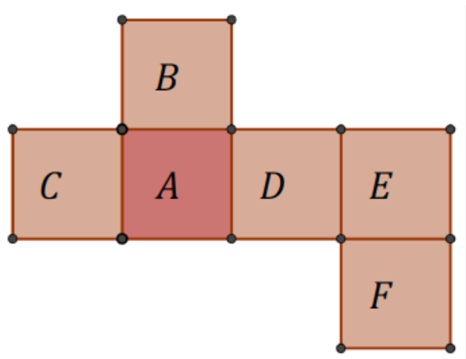
（請圈出適當答案）



7. 右圖為一正方體的展開圖，若把右面的摺紙圖樣

摺成一個正方體，字母____的面會與

字母「B」的面相對？

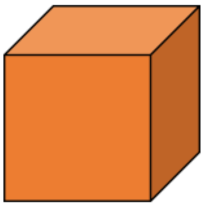
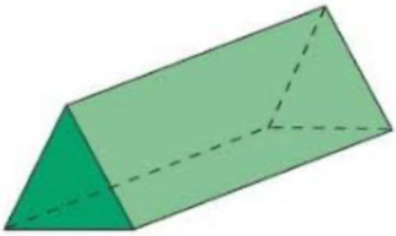
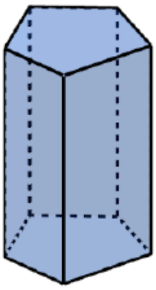
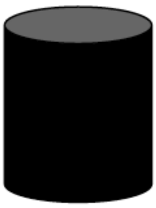


Appendix 2: In-class Worksheet (5 pages)

班別：　　　　　　　　　　　　　　　　　　　　學號：

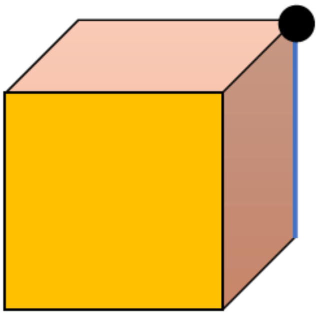
用 Geogebra 學習度量、圖形與空間

<u>重溫直立角柱</u>

<u>重溫頂點、棱及面</u>

你能辨認出**頂點**、**棱**及**面**嗎？請填寫表格內。



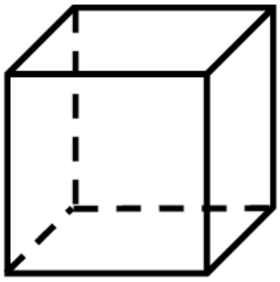
	
	

1. 6 個頂、9 條棱和 5 個面的**直立角柱**是甚麼？ ___________柱體

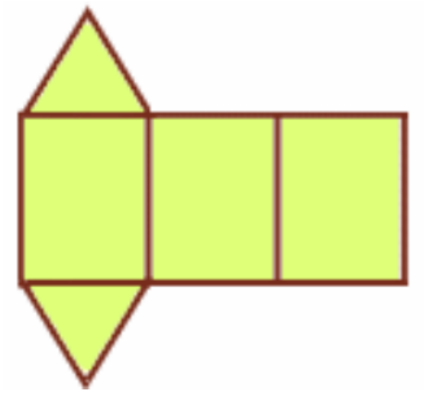
2. 一個**正五角柱體**會有______個面，______條棱，______個頂點。

立體圖形展開圖

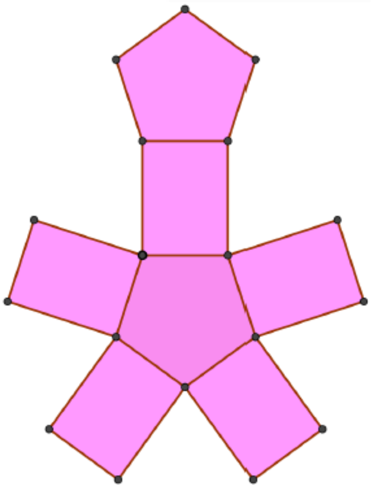
3. 圖中所示為一個正方體。描繪正方體的兩個摺紙圖樣。



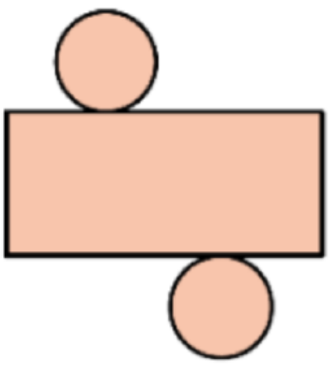
4. 在空格內寫出下列各摺紙圖樣能摺出的立體的名稱。



______柱體



______柱體



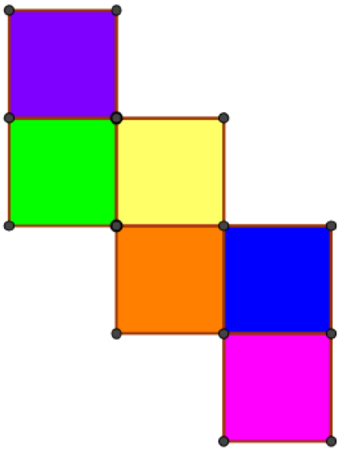
______柱體

5. 若把右面的摺紙圖樣摺成一個正方體，

(a) ____色面會與藍色面**相對**。

(b) ____色面會與黃色面**相對**。

(c) ____色面和____色面會同時與綠色面和橙色面相鄰**。



6. 若把右圖的摺紙圖樣摺成一個長方體，

(a) M 點會與____點和____點重合。

(b) 邊____會與 SR 重合。