 

# Geometry learning strategies with optimised technology to improve the performance of undergraduate mathematics students

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ABSTRACT: In the globalisation era, students are required to have the competence to use the learned theory and technology tools to solve various problems they face, in any country. To meet that requirement, effective and efficient learning strategies are needed in different disciplines. This study was aimed to construct geometry learning strategies by optimising the role of technology to improve the performance of undergraduate mathematics students in Indonesia. The findings indicate that the strategies used by students in choosing theories and technologies were appropriate to the problems, and led to effective and efficient solutions. Based on a questionnaire, it was established that students' motivation to learn geometry had increased, because they appreciated the benefits of the studied theory; they were excited when they realised how much technology could make solving problems easier; and they had improved their mathematical competence and were more confident, because they could demonstrate their ability to solve various problems. By applying the developed learning strategies, the performance of students has increased.

## INTRODUCTION

In the globalisation era, students are required to have the competence to use the learned theory and technology tools to solve various problems they face, in any country. In higher education institutions, teaching methods should be focused on solving various problems, including not only the knowledge system, but also the system of professional skills and abilities that graduates will need [1]. Therefore, appropriate training in how to take advantage of the learned theory and technology in problem solving is so important for students. Learning management systems for teaching that focuses on experiment and practice using computer simulations are essential to efficiently and quickly teach complex principles or theories [2].

In order for graduates to have mathematical competence as expected, effective and efficient learning strategies are needed. Learning strategies are educational tools that empower people and create opportunities to overcome barriers and obstacles to access education. The development of learning strategies is fundamental to complementing learning [3], and it is crucial across all disciplines. Many factors affect students' mathematics performance, such as motivation, learning style, anxiety, working memory capacity, cognitive style, etc. [4]. These factors need to be considered in developing learning strategies, so that the desired results are obtained [5].

Geometry includes space and shape concerning distance, size and relative positions of figures. Geometry is a very important mathematical branch, and many career jobs involve geometry, such as architect, mechanical engineer, technician, surveyor, draftsman, and many others. Most students consider geometry difficult to learn, are not interested in learning further; they often experience anxiety when studying it, and are not able to use geometric theory to solve the problems they face [6].

Undergraduate mathematics students study mathematics in theory, and often have difficulty in applying the theory learned in lectures to solve various practical problems around them. Therefore, development of appropriate geometry learning strategies by optimising technology is needed to increase students' motivation, confidence and competence in mathematics.

## LEARNING STRATEGIES BY OPTIMISING TECHNOLOGY TO IMPROVE MATHEMATICS PERFORMANCE

Technology and learning mathematics are two things that cannot be separated, especially in higher education. Technology in learning has various functions. Technology can be used to increase motivation and reduce students' mathematics anxiety; technology can also facilitate student creativity and ideation, and it supports the reasoning and execution of student plans [7]. Activities that connect science and technology will not only cultivate creative thinking skills, but also analytical and practical skills [8].

In addition, with technology students can become aware that some teaching/learning methods used so far are inefficient or unsuitable for today's educational environment. Therefore, learning strategies that optimise the role of technology are needed, so that students could use technology competently, choose the technological tools that are appropriate to the situation they face and as a result improve their mathematical performance.

The subjects of this study were second-year mathematics students at the State University of Surabaya (Universitas Negeri Surabaya), Indonesia who took a geometry course. A total of 64 students participated in this study.

The learning strategies designed to improve students' mathematical performance in this study are as follows:

Strategy 1: Strengthen the mastery of concepts and familiarise students with the characteristics and properties of geometric objects.

This strategy refers to the first step in learning geometry. Before students can apply theory, they need to comprehensively study and fully understand the underlying theoretical concepts. Some of the concepts and theorems that students have to learn are related to geometric objects, congruence, similarity, distance, centre point, affine functions, isometry, etc. Some of the tasks given to students are to prove theorems and problems related to geometric concepts, as given below.

Concept-based tasks in geometry classes:

1. Various ways of proving the Pythagorean Theorem

Students are asked to prove the Pythagorean Theorem using the axiomatic method and several other methods. These methods are illustrated in the following figure:

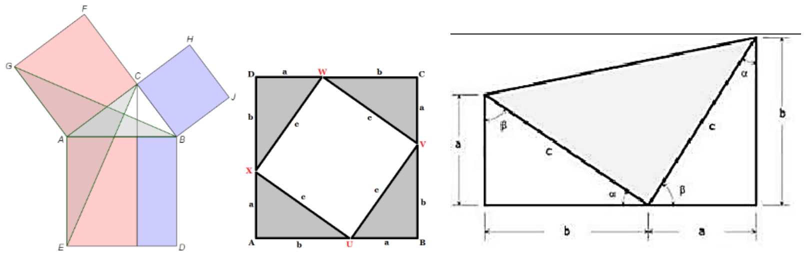
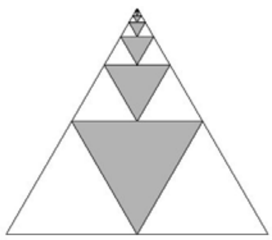



Figure 1: Some methods to prove the Pythagorean Theorem.

2. Students are asked to prove the theorems of geometry, such as the triangle similarity theorem.

Strategy 2: Motivate students by showing that geometry can make mathematical proofs easier (prove without words).

This strategy aims to motivate students to learn geometry by showing the benefits of geometry they are studying for other mathematical theories. An activity related to this is showing some geometric shapes that can be used to more easily argument and prove a given theorem. The following geometric figure is an example to make it easier to prove a number series:



$$\frac{1}{3} = \sum_{i=1}^{\infty} \frac{1}{4^i} = \frac{1}{4} + \frac{1}{4^2} + \frac{1}{4^3} + \frac{1}{4^4} + \frac{1}{4^5} \cdots$$

Figure 2: Geometric shape showing a series of numbers.

Strategy 3: Focus on the material or method, where students usually make the most mistakes and emphasise how technology could be used in those cases, so that students realise that technology is helpful, and are convinced that this approach will result in better outcomes.

Based on the experience of teaching mathematics, a teacher will find a topic, material or method, where students often make mistakes. This needs to be pointed out to students to make them aware that their mistakes can be reduced or eliminated with the help of technology, and the process simplified. In geometry, a common mistake that students often make is the problem of determining the number of objects in a container. Most students solve this by dividing the area of the container by the area of the object or dividing the volume of the container by the volume of the object. In this case, technology can be used to describe the specific situation, so that students are aware of the errors in the method used.

In geometry, students often find it difficult to find the shortest path between two points if there are obstacles between them. Most students do it by trial and error, and do not use the geometric properties learned. Sometimes, it is difficult to check the answer to find the optimum value theoretically, so the technology used makes it easier to check whether the answer is optimal or not. For example, technology is used to test the conjecture and find the desired result, and in the next step, students practice giving their reasoning based on the relevant geometric theory. It is hoped that after using technology several times and providing theoretical reasons for their solutions, students will be able to master the theory and apply it to solve other problems.

Strategy 4: Showing students how the theory learned can be used to solve problems faced in the surrounding environment more effectively and efficiently.

In this strategy, it is crucial to come up with assignments in which students demonstrate their competence in using the learned theory to efficiently and effectively solve problems around them.

A task on the application of theory to problems in the surrounding environment:

1. A bridge will be sturdy if both sides have the same shape. Students are asked to plan how to do it and then carry out the plan to the field to check the similarity of the two sides of the bridge near campus. Before going to the bridge, students are asked to write their plans based on imagination and theory, and then test them based on the conditions in the field. It is hoped that students will realise that the theory they have learned really helps.
2. Students are asked to determine the minimum length of a cable that will be installed on their classroom walls measuring 4 m x 3 m with a classroom height of 3 meters from end to end of the diagonal of the room, and determine the cable path. The following figure illustrates the situation:

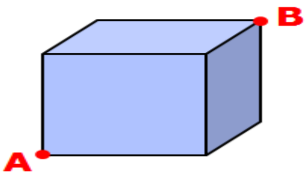



Figure 3: A geometric shape that helps to find the shortest path from A to B.

3. In the campus area, there is a water reservoir and there is a place in the centre that is 4 meters from the edge of the water reservoir boundary. There are two pieces of wood with a length of 3.9 meters. Students are asked to determine how to cross to the centre area using the wood as is without using nails to connect the wooden pieces. A sketch of the water reservoir and central area is given below:

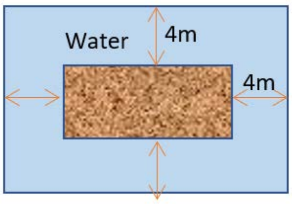



Figure 4: The sketch of the water reservoir.

4. Students are asked to determine the point along the edge of the water reservoir, so that the path taken from picking up a bucket in the warehouse, then fetching water at the selected point and watering the plants on the campus is the shortest. The following figure illustrates the situation:

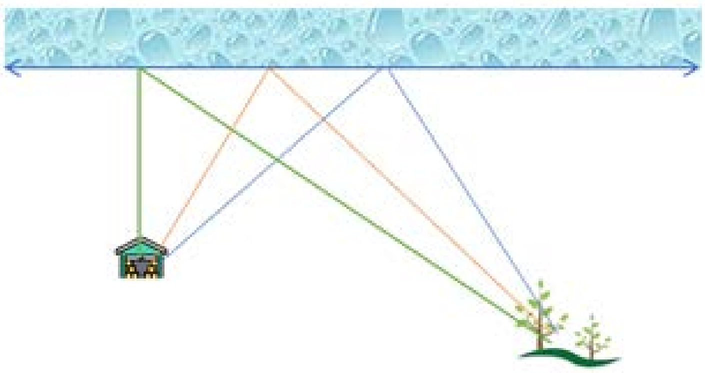


Figure 5: Paths from the warehouse to the water reservoir to the plants.

Strategy 5: Facilitate students applying the geometric theory to culture and society.

One of the learning outcomes of the national standard of higher education is that graduates are expected to have the competence to apply the learned theory to culture and society. In this regard, students are allowed to choose objects in nature or local works of art, in the form of traditional house motifs, batik motifs, shawl motifs, carved motifs or others to be classified based on their geometric properties.

The results of classification based on geometric properties are very useful for grouping objects based on the same geometric properties, which often facilitates arrangement or storage including art images by utilising an object generator to minimise the memory needed to store. By storing the generated parts, using classification codes and with the help of technology, a complete picture can be obtained.

Strategy 6: Assignment of technology-based projects to solve problems in the field to train reasoning, collaboration and communication skills.

This encourages students to collaborate to design their strategies, make plans and choose the right technology to carry out plans, evaluate results and revise them in an effective and efficient manner. After that, students present the obtained results. While working together, students collaborate, select and apply the right technology to solve the encountered problems, and communicate the results.

Project-based tasks with the use of appropriate technology to solve problems effectively and efficiently:

1. Determining the location of a community health centre in the area where students live.
2. Designing a three-dimensional map of tourist attractions for the area where students live.

RESULTS AND DISCUSSION

As mentioned above, 64 second-year mathematics students at the State University of Surabaya (Universitas Negeri Surabaya), Indonesia, who took geometry course participated in this study.

The students felt happy and excited when they could prove several series of numbers using geometric figures because this was new knowledge for them. They realised how geometry made it easier to see proofs of a series of numbers.

For the problem of determining the number of water boxes in a container, as expected, more than half of the students used the method of dividing the volume of the container by the volume of the water box. After they were asked to illustrate the position of the water box in a container with the help of software, they realised that the method used was wrong. Once realising what the correct method was, then in the final test, there were no students who used the area or volume division method again. In this case, the method with the help of technology was successful in reminding students that the method used so far was wrong, and must be modified according to the situation.

As for the shortest path problem, after trying several solutions with the help of GeoGebra software, students could find the right solution, and after analysing the results, they could provide the theoretical reasons for their solution. In this case, technology played a role as a helper in checking hypotheses and strengthening the mastery of geometric concepts.

In regard to the problem of congruence testing of two sides of the bridge, students prepared three different groups of plans before going to the bridge. In the first group, half of the students planned to measure all sides and angles on both sides of the bridge. In the second group, a quarter of the students planned to measure all sides without measuring the angles of the bridge, arguing that two triangles would be congruent if all three sides were congruent (the s-s-s principle), and another quarter of the students planned to measure the lengths of the sides and two angles on that side using the a-s-a principle.

In this case, it can be seen that students did not pay too much attention to the field conditions, but focused more on one of the theorems about the congruence they had chosen. It was during the execution of the plan on the bridge that most students realised that their plan could not be implemented, because it was difficult to measure all sides of the bridge. After all, it was too high. In the field, they found that to test whether the two sides of the bridge are congruent, it is not necessary to measure all sides of the bridge, but simply to use the a-s-a principle, which is to measure the reachable side and measure the size of the two angles on that side. With this problem, students could feel the benefits of the learned theory that could make it easier to solve the problem.

Meanwhile, when solving the problem of determining the shortest cable length to connect two points on the diagonal of the classroom, some students had difficulty when faced with the field conditions. Only after they modelled the classroom with the shape of a block, analysed the properties of the blocks and used the Pythagorean principle, they found the right solution. In this case, the modelling of the problem in a real situation helped students to find the right solution.

The following figure, Figure 6 shows the models made by students:

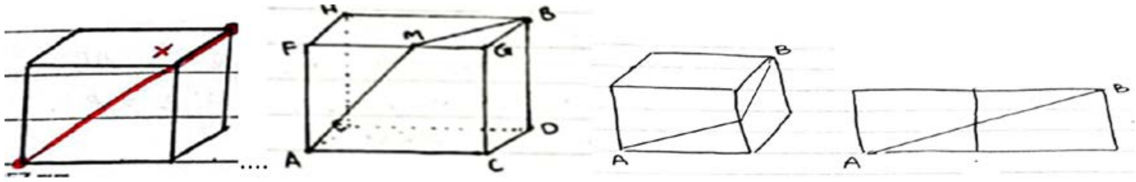


Figure 6: Some models made by students.

The problem of using two wooden planks to cross the water reservoir is different from the problem of determining the length of the cable. Students did not immediately find solutions based on the created models before going to the field. Almost all students thought that trying all the wooden planks' positions can solve this problem. After that, students modelled the results they found and gave logical reasons based on mathematics.

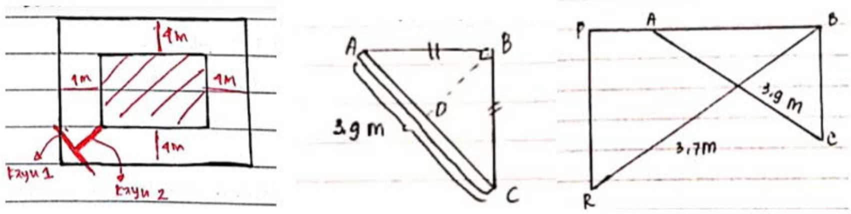


Figure 7: Models made by students with their reasoning.

The problem on finding the shortest path from the location of the bucket to the location of the water collection, and the location of the plants to be watered was a difficult problem for students. Even though they used a model, students still could not find the right solution. With the help of software, some students were successful, although they could not give a logical reason why it was applicable. After a reminder about the geometric theorems related to this problem and training students on similar problems most students were able to find the right solution on the final test.

In the task of grouping natural objects or cultural works of art, students managed to group flowers, sea animals, carvings and other artistic works based on their geometric properties, by observing the rotational and reflection properties of these objects.

In the project task of determining the location of a community health centre adapted to the conditions of the area where students live, students succeeded in determining a strategy by taking into account the location factor of existing health centres, population distribution, road or transportation conditions, and using the principles of Voronoi diagrams, as well as Google Maps and GeoGebra.

The project task related to making a three-dimensional tourist map of the area where students live, students demonstrated their skills in collecting data on tourist objects, positions and transportation routes, and designing three-dimensional maps that matched the field conditions. By utilising the appropriate software, various three-dimensional maps were obtained that describe tourist attractions that can be visited along with a description of their location. Some of the results of student assignments are shown below:

Figure 8: The three-dimensional maps of tourist attractions of Mojokerto and Bantul created by students.

Based on the questionnaire given at the end of the class, it was found that almost all students felt happy and motivated to learn geometry. The numerous activities during the classes made them realise the importance of the studied theory in solving the problems they encountered.

This finding is consistent with the opinion that the combination of technology-based problem solving and a constructivist approach is beneficial to increasing student involvement to a high level, and hence to improving their performance [9].

## CONCLUSIONS

The learning strategies that were carried out can increase students' motivation in learning geometry and improve their abilities in using the geometric theory to solve various problems around them, which results in an improved mathematical performance.

The use of technology in learning can help students to realise the mistakes they often make, help them to find the optimal solution more easily, and also facilitate in mastering the concepts learned and help execute plans for solving problems.

Students feel more confident and competent, because they can demonstrate their ability to solve various problems using the learned theory and the appropriate technology. In other words, the constructed learning strategies can improve students' mathematical performance.

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## REFERENCES

1. Gravemeijer, K., Stephan, M., Julie, C., Lin, F.-L. and Ohtani, M., What mathematics education may prepare students for the society of the future? *Inter. J. of Science and Mathematics Educ.*, **15**, 105-123 (2017).
2. Wattanasin, W., Chatwattana, P. and Piriyasurawong, P., Engineering project-based learning using a virtual laboratory and mixed reality to enhance engineering and innovation skills. *World Trans. on Engng. and Technol. Educ.*, 19, **2**, 232-237 (2021).
3. Khanal, B., Panthi, R.K., Kshetree, M.P., Acharya, B.R. and Belbase, S., Mathematics learning strategies of high school students in Nepal. *SN Social Sciences*, 1, **7**, 1-28 (2021).
4. Juniati, D. and Budayasa, I.K., The influence of cognitive and affective factors on the performance of prospective mathematics teachers. *European J. of Educational Research*, 11, **3**, 1379-1391 (2022).
5. Berger, J-L. and Karabenick, S.A., Motivation and students' use of learning strategies: evidence of unidirectional effects in mathematics classrooms. *Learning and Instruction*, 21, **3**, 416-428 (2011).
6. Juniati, D. and Budayasa, K., Field-based tasks with technology to reduce mathematics anxiety and improve performance. *World Trans. on Engng. and Technol. Educ.*, 19, **1**, 58-64 (2021).
7. Dick, T.P. and Hollebrands, K.F., Focus in High School Mathematics: Technology to Support Reasoning and Sense-making. Reston, VA: National Council of Teachers of Mathematics (2011).
8. Avsec, S. and Jerman, J., Self-efficacy, creativity and proactive behaviour for innovative science and technology education. *World Trans. on Engng. and Technol. Educ.*, 18, **4**, 369-374 (2020).
9. Attard, C., Engagement, technology, and mathematics: students' perceptions. *Southeast Asian Mathematics Educ. J.*, 4, **1**, 23-33 (2014).