The 2nd International Conference on Mathematics Education and Technology (ICOMET) 2023
ISSN 2986-8513 | pp. 108-116 (2023)
Publisher: University of Islam Malang

WHY ORIENTATION SPATIAL STRATEGIES ARE IMPORTANT IN LEARNING GEOMETRY?

Indah Setyo Wardhani[1*]

[1]Primary School Teacher Education Departmen, Faculty of Science Education, University of Trunojoyo, Jl. Raya Telang, Kamal, Bangkalan, Madura, Jawa Timur, Indonesia

ABSTRACT

Spatial orientation strategies are important in learning geometry to describe the position of objects from a certain point of view. This research aims to identify elementary school students' spatial orientation strategies in solving spatial problems with the help of teaching aids. The methodology used is case study research. A total of 21 fifth grade students at SDN Getas 02 Nganjuk, East Java were the research subjects. Subjects were divided into 5 groups based on academic ability and gender. Data collection through group work results. Data analysis takes the form of presenting data and drawing conclusions. The results of the identification are: (a) through visual aids, the group spatial orientation strategy is well developed, (b) props in the form of a cube model with color specifications make it easier for students to show opposite sides of the net, compared to a cube model with symbol specifications numbers, (c) it is easier for group members to write color cadences on cube nets, rather than number codes, (d) the complexity of the shape of the nets is predicted to have an impact on students' inaccuracy in placing specific signs in the nets. The implementation of this research is in the form of applying spatial orientation strategies in learning geometry.

Keywords: geometry, spatial orientation

1. Introduction

Geometry is material that needs to be studied because it is explored to solve problems. Studying geometry requires spatial skills (NCTM, 2000; Izard, 2020; Carbonell-Carrera, et al., 2021). According to NCTM (2000), spatial skills are needed to solve geometric problems using two and three-dimensions objects. Spatial skills are necessary when: (a) using two-dimensional shapes to represent three-dimensional objects, (b) interpreting images, (c) imagining objects in different orientations, manipulating three-dimensional objects, and reconstructing two and three-dimensional objects. Spatial skills and objects in geometry are interrelated, where spatial skills are a type of skill that involves two and three-dimensions (Baranová & Katreničová, 2018), while two and three-dimensions are objects in geometry (NCTM, 2000).

---

*) Corresponding Author.
E-mail: indahsetyo.wardani@trunojoyo.ac.id
Phone: +62857344384

Spatial skills are an important agenda in the field of education because they help a person's activities. Spatial skills help someone navigate (Wakabayashi & Ishikawa, 2011; Uttal, et al., 2013; Atit, et al., 2020). Spatial skills help someone learn material at school (Clements, 1999; Yilmaz, 2009; Nagy-Kondor, 2016). Spatial skills help someone solve mathematical problems (NRC, 2006; Uttal, et al., 2013; Anderson, 2014), as per Anderson's research results (2014), 38.16% of mathematics story problem solving performance is supported by spatial skills. Spatial skills help illustrate multiplication material (for example 4 x 5 = 20) with grids (Clements, 1999). Spatial skills help illustrate material comparing fractional values (for example 1/3 and 1/4) with circles or squares (Clements, 1999). Spatial skills help imagine numbers on a number line with small numbers placed on the left and vice versa (Gunderson, et al., 2012). Someone with good spatial skills can excel in mathematics (Borriello & Liben, 2018; Gilligan, et al., 2019; Rittle-Johnson, et al., 2019) and be successful in completing work in STEM fields (Buckley, et al., 2018; Gilligan, et al., 2019; Gagnier & Fisher, 2020). Children with good spatial skills can fold paper or assemble cubes (Atit, et al., 2020; Lee-Cultura & Giannakos, 2020).

Several researchers have described spatial skills support strategies from various points of view. Linn & Petersen, (1985), described the strategy components of spatial skills in the form of spatial perception, spatial visualization, and spatial rotation. According to (McGee, 1979; Maier, 1998) spatial skills are supported by spatial perception, spatial relations, spatial orientation, spatial rotation, and spatial visualization. Ramful, et al., (2017), grouped strategies for supporting spatial skills components in the form of spatial orientation, spatial visualization, spatial rotation. Wakabayashi & Ishikawa, (2011), concluded that spatial skills are supported by spatial visualization, spatial orientation, spatial relations. This difference in strategy does not need to be debated, because each component has a different description.

Spatial orientation strategy is a strategy in spatial skills to represent changes in objects from a certain point of view. There are two strategies, namely: (1) egocentric (cannot change the object's point of view) and (2) according to the point of view (according to the requested point of view). This strategy is needed to describe the position of objects from a certain point of view, reading maps, diagrams or pictures from different perspectives (Ramful, et al., 2017). For example in Figure 1.

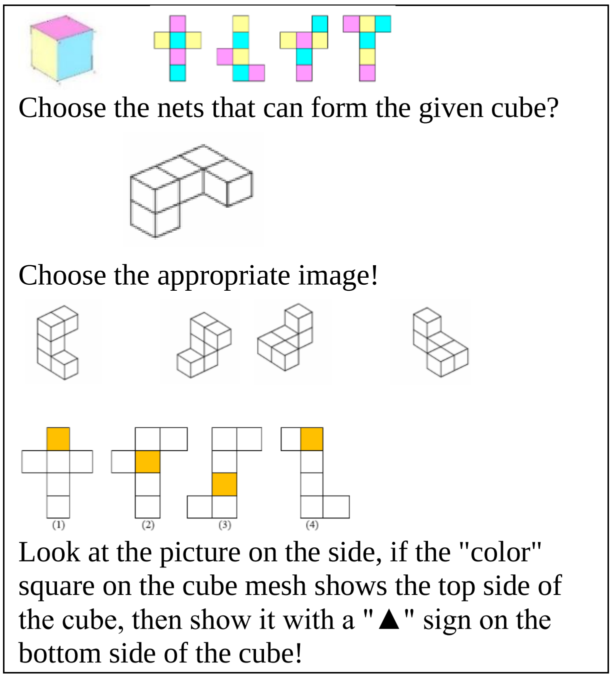


Figure 1. Example of a Problem Involving Spatial Orientation

The education curriculum in Indonesia instructs elementary school students to have good student spatial orientation strategies. Through the Permendikbudristek number 7 of 2022, namely, "spatial regarding flat shapes and space and their properties to explain the environment", students are expected to have learning experiences in the form of spatial orientation strategies. This strategy is important, as in class V, this strategy can, 1) help class V students construct cube nets from a certain orientation, 2) help students construct the surface area of a cube in class VI, and 3) help students construct flat sided shapes in middle school.

The results of observations of learning cube nets and blocks in September 2023 of 21 class V students at SDN Getas 02 Nganjuk, it is known that students' spatial orientation strategies have not developed. It is known that students are still confused about showing opposite sides of the cube in their nets. Like one of the results of the student's work in Figure 2, where the student made a mistake in showing the opposite sides of the cube in his net.

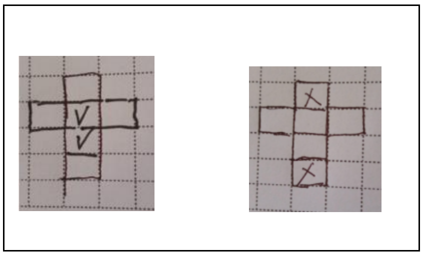


Figure 2. Example of Student Answers

The aim of this research is to identify elementary school students' spatial orientation strategies after solving problems with the help of teaching aids. The props used are, (a) a model of an object resembling a cube with opposite sides given the same color, and (b) a model of an object resembling a cube with opposite sides given the same number, (c) 3 types of cube net models.For every data or quote statements which are taken from other literatures, the author must write down the reference source. References or citations are written in the description/text with the arrangement of the author's name followed by the year (Irwan and Salim, 1998). If the authors are more than two, then only the name of the first author is written followed by "et al." (Bezuidenhout et al., 2009). Everything referenced in the text must be listed in the

Bibliography section, and vice versa (Wang et al., 2011).

2. Research Methods

This type of research is a case study (Creswell & Creswell 2018). 21 fifth grade students at SDN Getas 02 Nganjuk, East Java were chosen as research subjects. The research subjects (15 female students and 6 male students) were divided into 5 groups (each group consisting of 4-5 students). Group division based on academic ability and gender. In one group, it consists of students with high, medium and low academic abilities as well as male and female students. The reasons are, (a) not all individuals are equipped with spatial abilities (Cohen & Hegarty, 2014) and (b) boys' spatial abilities are more dominant than girls (Battista, 2020). Hence, male students were divided evenly in each group. Data was obtained from the results of group discussions in completing student activity sheets on cube nets from certain orientations.

3. Results and Discussion

Activities in solving spatial problems are carried out by arranging specific signs from known cubes in the nets provided. The props used are a model of an object resembling a cube with opposite sides given the same color and a model of an object resembling a cube with opposite sides given the same number as in Figure 3 below. Through the props provided, students can recognize the characteristics of specific cubes (specially marked). Next, group members are asked to imagine and manipulate to be able to create cube nets from specific cubes (specially marked) and represent them by placing appropriate specific marks on the cube nets given.

Figure 3. Model of an Object Resembling a Cube With Opposite Sides Given the Same Color/Number

Student activity in problem 1, namely "Through a model of an object resembling a cube with opposite sides given the same color, students in groups are asked to complete the net with the appropriate color code (the color on the net is written with the code: red (M), yellow (K) and blue (B)), so that when the net is formed into a cube, it will become a known cube."

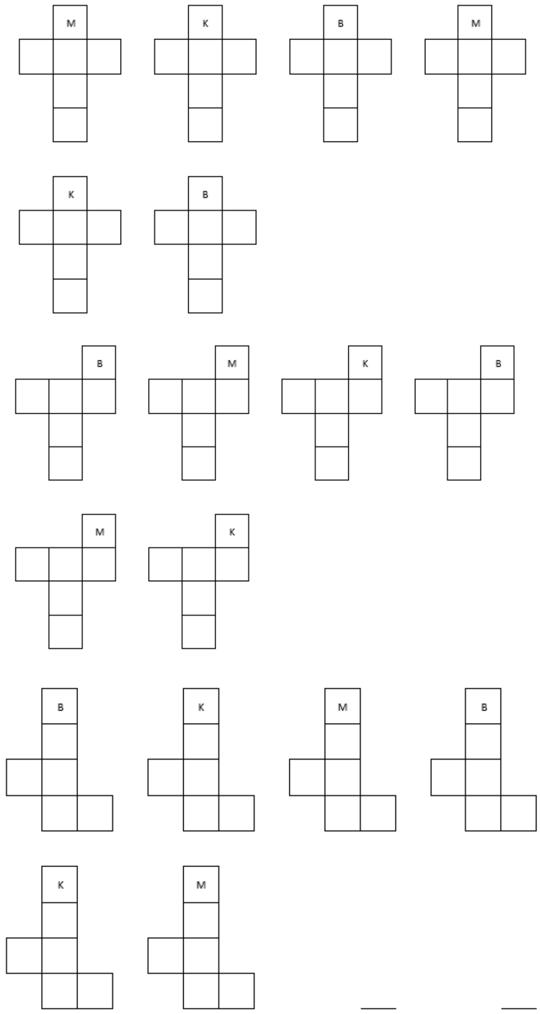
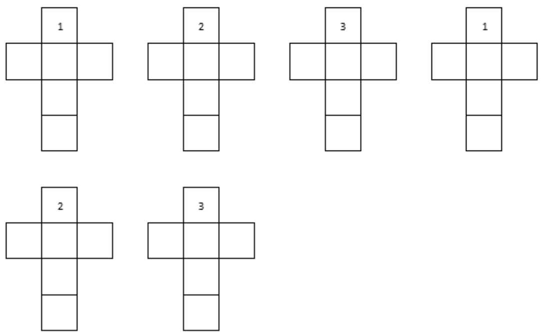


Figure 4. Cube Nets in Problem 1

The activity in problem 2, namely "through a model of an object resembling a cube with opposite sides given the same number, students in groups are asked to complete the net with the appropriate color, so that when the net is formed into a cube, it will become a known cube.



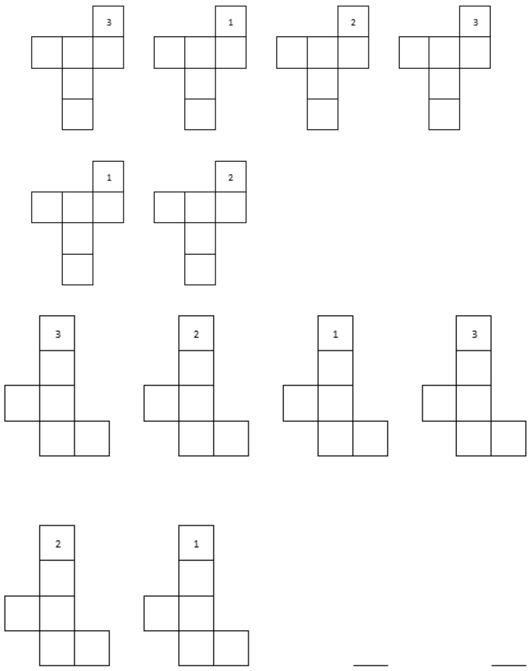


Figure 5. Cube Nets in Problem 2

The activity of imagining and manipulating spatial objects is carried out in the following steps: (a) students in groups are asked to observe props 1 and 2 from various points of view, (b) students in groups are asked to show pairs of opposite sides in props 1 and 2 , (c) students were asked to discuss in groups to write color codes on the nets after observing props 1 and 2. The results of the group members' work are summarized in Table 1 as follows.

Table 1. Number of Nets Compiled by Each Group

Group	The number of nets that can be arranged					
	1st Activity and 1st Props			2st Activity and 2st Props		
	Nets 1	Nets 2	Nets 3	Nets 1	Nets 1	Nets 2
1	3	2	1	2	1	1
2	4	2	0	3	2	2
3	3	2	0	2	1	0
4	3	1	0	2	1	0
5	4	1	1	2	1	0

Activity 1 uses a media model of an object resembling a cube with opposite sides given the same color. It was concluded that 2 groups succeeded in arranging 4 nets with different colors correctly, and 3 groups succeeded in arranging 3 nets with different colors. correctly. These results conclude that the spatial orientation skills of the 2 groups have developed well, and the spatial orientation skills of the 3 groups have developed. Examples of group work results are as follows.

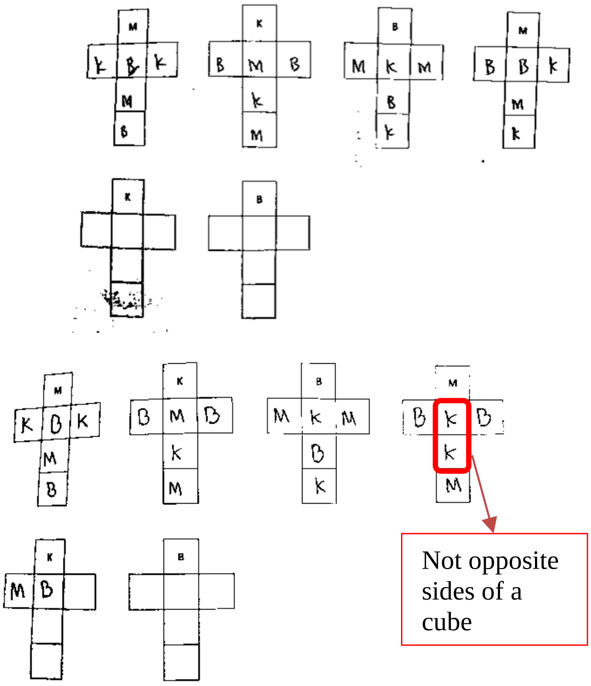
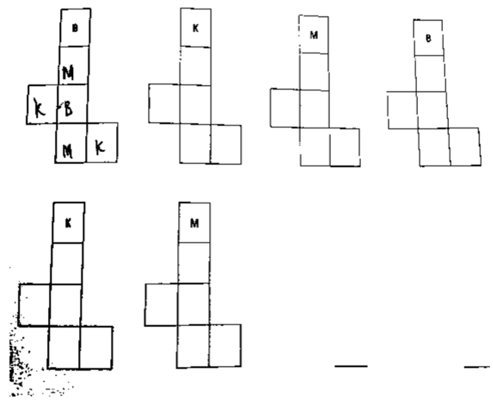


Figure 6. Example of Group Work For Activity 1, Props 1

The second activity used a media model of an object resembling a cube with opposite sides given the same color. It was concluded that 3 groups succeeded in arranging 2 nets with different colors correctly, and 2 groups succeeded in arranging 1 net with a different color. Correct. These results conclude that the spatial orientation skills of the 5 groups have developed. Examples of group work results are as follows.



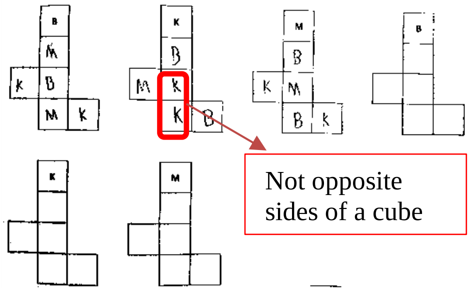


Figure 7. Example of Group Work For Activity 2, Props 1

The third activity used a media model of an object resembling a cube with opposite sides given the same color. It was concluded that 2 groups had succeeded in arranging 1 net with a different color correctly, and 3 groups had not succeeded in arranging nets with different colors. These results conclude that the spatial orientation skills of the 2 groups have developed. Examples of group work results are as follows.

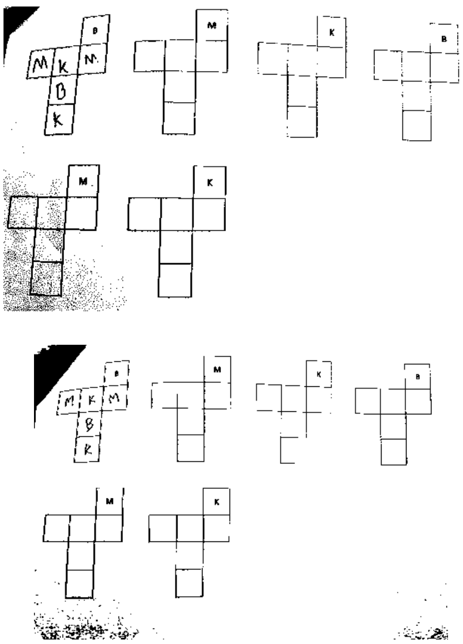


Figure 8. Example of Group Work For Activity 3, Props 1

The 1st activity uses a model of an object resembling a cube with opposite sides given the same number. It is concluded that 1 group succeeded in arranging 3 nets with different numbers correctly, and 4 groups succeeded in arranging 2 nets with different numbers. correctly. These results conclude that the spatial orientation skills of the 5 groups have developed. Examples of group work results are as follows.

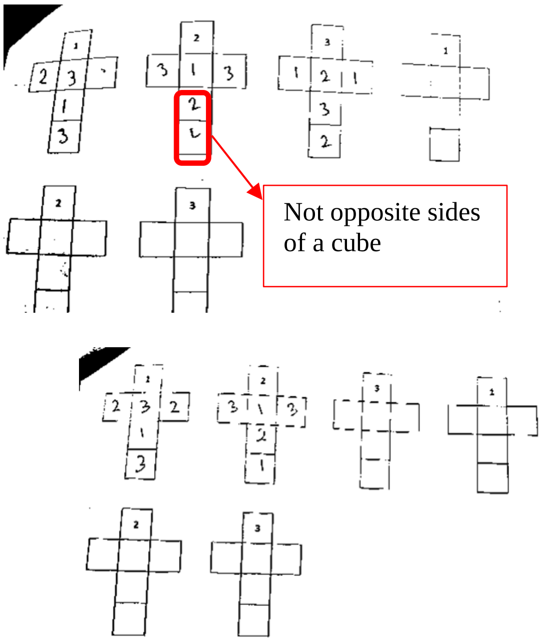
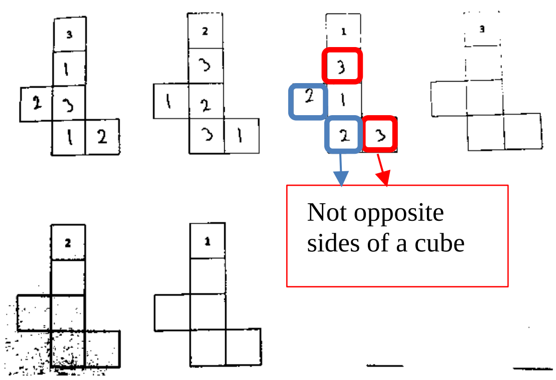


Figure 9, Example of Group Work for Activity 1, Props 2

The second activity used a media model of an object resembling a cube with opposite sides given the same number. It was concluded that 1 group succeeded in arranging 3 nets with different numbers correctly, and 4 groups succeeded in arranging 2 nets with different numbers. correctly. These results conclude that the spatial orientation skills of the 5 groups have developed. Examples of group work results are as follows.



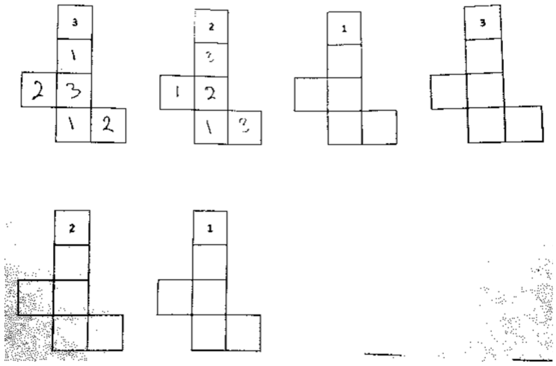


Figure 10, Example of Group Work for Activity 2, Props 2

The third activity uses a model of an object resembling a cube with opposite sides given the same number. It is concluded that 1 group succeeded in arranging 2 nets with different numbers correctly, and 1 group succeeded in arranging 1 net with different numbers. correctly, and 3 groups have not succeeded in arranging nets with different numbers correctly. These results conclude that the spatial orientation skills of the 2 groups have developed. Examples of group work results are as follows.

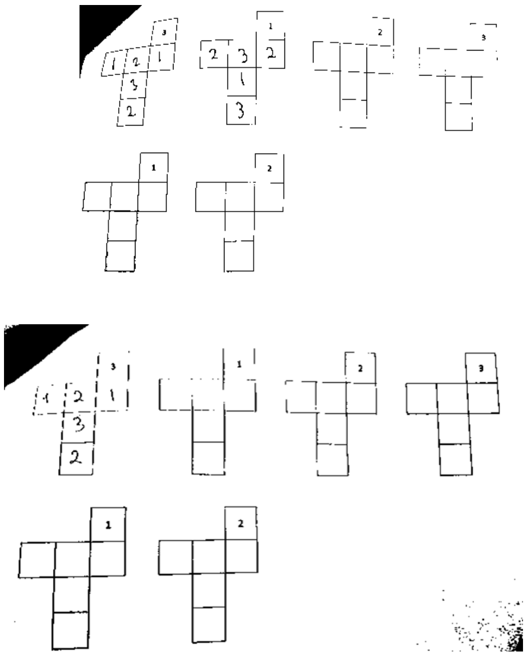


Figure 11, Example of Group Work for Activity 2, Props 2

Spatial orientation activities assisted by props can be managed using an imagiatic approach (Cohen & Hegarty, 2012, 2014). This approach has the potential to provide educational experiences for children. Children's educational experiences must be rich, so that children's cognitive development can run optimally (Subanji, 2013). When a child's cognitive development is running optimally, they can develop spatial orientation strategies.

Students tend to find it easier to use media modeling objects resembling cubes with opposite sides given the same color compared to media modeling objects resembling cubes with opposite sides given the same numbers. Search results from previous research conclude that, (a) color has a strong influence on the human cognitive system and has been proven to have an influence on memory performance (Wichmann, Sharpe & Gegenfurtner, 2002), (b) color can help individuals to remember certain information because can increase a person's level of attention (Dzulkifli & Mustafar, 2013), (c) types of colors are also known to have an influence on the color binding process in the memory representation of objects in human cognitive (Kuhbandner, Spitzer, Lichtenfeld & Pekrun, 2015), (d) DePorter and Hernacki (2013) stated that individuals tend to be able to remember things that are abstract, colorful, and striking. (e) Sujarwo and Oktaviana (2017) stated that color has an influence on short-term memory abilities, where the group that was given color treatment had better short-term memory abilities than the group that was not given treatment.

The complexity of cognitive processes can be an obstacle in solving problems (Sternberg, 2009; Scunk, 2013; Wang, et al, 2014; Yilmas, 2017). Meanwhile, according to Wulandari (2019), a person's cognitive process in spatial orientation is more complex than other components of spatial skills. This condition can be seen from the results of the group's work in arranging nets with specific signs as presented in Table 1. The more complex (varied) the shape of the net is, the fewer the number of specific signs that can be arranged correctly. This means that the complexity (variation) of the shape of the net has an impact on students' inaccuracy in placing specific signs in the net.

4. Conclusions

Spatial orientation strategies are used to view objects from a certain point of view. In this research, spatial orientation strategies are carried out with the help of props. Props have the potential to make it easier for someone to imagine and manipulate objects in geometry. Geometry itself includes two and three dimensional objects, so a spatial orientation strategy is needed to study it.

The results of the identification are: (a) through visual aids, the group spatial orientation strategy is well developed, (b) props in the form of a cube model with color specifications make it easier for students to show opposite sides of the net, compared to a cube model with symbol specifications numbers, (c) it is easier for group members to write color cadences on cube nets, rather than number codes, (d) the complexity of the shape of the nets is predicted to have an impact on students' inaccuracy in placing specific signs in the nets. The activity of imagining and manipulating spatial objects in this research uses a model of an object resembling a cube with opposite sides given the same color, and the signs coded by each group on the cube net are in the form of an abstract code, namely: red (M), yellow (K) and blue (B). Other researchers who want to develop similar research are advised to use concrete signs, namely red, yellow and blue objects.

5. References

Atit, K., Power, J. R., Veurink, N., Uttal, D. H., Sorby, S., Panther, G., Msall, C., Fiorella, L., & Carr, M. (2020). Examining the role of spatial skills and mathematics motivation on middle school mathematics achievement. *International Journal of STEM Education*. https://doi.org/10.1186/s40594-020-00234-3

Baranová, L., & Katreničová, I. (2018). Role of descriptive geometry course in development of students' spatial visualization skills. *Annales Mathematicae et Informaticae*. https://doi.org/10.33039/ami.2018.04.001

Bao, Min, Jing Xie, Aigars Piruska, and Wilhelm T.S. Huck. 2017. "3D Microniches Reveal the Importance of Cell Size and Shape." *Nature Communications*.

Battista, M. T. (2020). Spatial Visualization and Gender Differences in High School Geometry. *Journal for Research in Mathematics Education*. https://doi.org/10.5951/jresematheduc.21.1.0047

Borriello, G. A., & Liben, L. S. (2018). Encouraging Maternal Guidance of Preschoolers' Spatial Thinking During Block Play. *Child Development*. https://doi.org/10.1111/cdev.12779

Buckley, J., Seery, N., & Canty, D. (2018). A Heuristic Framework of Spatial Ability: a Review and Synthesis of Spatial Factor Literature to Support its Translation into STEM Education. In *Educational Psychology Review*. https://doi.org/10.1007/s10648-018-9432-z

Carbonell-Carrera, C., & Medler, S. H. (2017). Spatial orientation skill improvement with geospatial applications: Report of a multi-year study. In *ISPRS International Journal of Geo-Information*. https://doi.org/10.3390/ijgi6090278

Carbonell-Carrera, C., & Saorin, J. L. (2018). Virtual learning environments to enhance spatial orientation. *Eurasia Journal of Mathematics, Science and Technology Education*. https://doi.org/10.12973/ejmste/79171

Cheng, Y. L., & Mix, K. S. (2014). Spatial Training Improves Children's Mathematics Ability. *Journal of Cognition and Development*. https://doi.org/10.1080/15248372.2012.725186

Clements, D. H. (1999). Geometric and spatial thinking in young children. In *Mathematics in the early years*.

Cohen, C. A., & Hegarty, M. (2012). Inferring cross sections of 3D objects: A new spatial thinking test. *Learning and Individual Differences*. https://doi.org/10.1016/j.lindif.2012.05.007

Cohen, C. A., & Hegarty, M. (2014). Visualizing cross sections: Training spatial thinking using interactive animations and virtual objects. *Learning and Individual Differences*. https://doi.org/10.1016/j.lindif.2014.04.002

Creswell, J. W., & Creswell, J. D. (2018). Research and Design Qualitative, Quantitative and Mixed Methods Approaches. In *Thousand Oaks California*.

DePorter, B., & Hernacki, M. (2013). *Quantum Learning*. Bandung: Kaifa Learning

Dzulkifli, M. A. & Mustafar, M. F. (2013). The influence of colour on memory performance: A review. The Malaysian journal of medical sciences : MJMS.

Gagnier, K. M., & Fisher, K. R. (2020). Unpacking the Black Box of Translation: A framework for infusing spatial thinking into curricula. *Cognitive Research: Principles and Implications*. https://doi.org/10.1186/s41235-020-00222-9

Gilligan, K. A., Hodgkiss, A., Thomas, M. S. C., & Farran, E. K. (2019). The developmental relations between spatial cognition and mathematics in primary school children. *Developmental Science*. https://doi.org/10.1111/desc.12786

Gunderson, Elizabeth A., Gerardo Ramirez, Sian L. Beilock, and Susan C. Levine. 2012. "The Relation between Spatial Skill and Early Number Knowledge: The Role of the Linear Number Line." *Developmental Psychology*.

Hawes, Z., Lefevre, J. A., Xu, C., & Bruce, C. D. (2015). Mental rotation with tangible three-dimensional objects: A new measure sensitive to developmental differences in 4- to 8-year-old children. *Mind, Brain, and Education*. https://doi.org/10.1111/mbe.12051

Howse, T. D., & Howse, M. E. (2015). Linking the Van Hiele Theory to Instruction. *Teaching Children Mathematics*. https://doi.org/10.5951/teacchilmath.21.5.0304

Hwang, W. Y., Purba, S. W. D., Liu, Y. F., Zhang, Y. Y., & Chen, N. S. (2019). An Investigation of the Effects of Measuring Authentic Contexts on Geometry Learning Achievement. *IEEE Transactions on Learning Technologies*. https://doi.org/10.1109/TLT.2018.2853750

Izard, J. (2020). Developing Spatial Skills With Three-Dimensional Puzzles. *The Arithmetic Teacher*. https://doi.org/10.5951/at.37.6.0044

Kuhbandner, C., Spitzer, B., Lichtenfeld, S. & Pekrun, R. (2015). Differential binding of colors to objects in memory: red and yellow stick better than blue and green. *Front Psychol*, *6*. doi.org/10.3389/fpsyg.2015.00231

Kutluca, T. (2013). The effect of geometry instruction with dynamic geometry software; GeoGebra on Van Hiele geometry understanding levels of students. *Educational Research and Reviews*. https://doi.org/10.5897/ERR2013.1554

Lajoie, Susanne P. 2018. "Individual Differences in Spatial Ability: Developing Technologies to Increase Strategy Awareness and Skills." In *Aptitude: A Special Issue of Educational Psychologist*,.

Lawson, M. J., & Chinnappan, M. (2000). Knowledge connectedness in geometry problem solving. *Journal for Research in Mathematics Education*. https://doi.org/10.2307/749818

Lee-Cultura, S., & Giannakos, M. (2020). Embodied Interaction and Spatial Skills: A Systematic Review of Empirical Studies. In *Interacting with Computers*. https://doi.org/10.1093/iwcomp/iwaa023

Linn, M. C., and A. C. Petersen. 1985. "Emergence and Characterization of Sex Differences in Spatial Ability: A Meta-Analysis." *Child development*.

Luneta, Kakoma. 2015. "Understanding Students' Misconceptions: An Analysis of Final Grade 12 Examination Questions in Geometry." *Pythagoras*.

Maier, P. H. (1998). Spatial Geometry and Spatial Ability - How to Make Solid Geometry Solid. *Selected Papers from Annual Conference of Didactics of Mathematics 1996*.

McGee, M. G. (1979). Human spatial abilities: Psychometric studies and environmental, genetic, hormonal, and neurological influences. *Psychological Bulletin*. https://doi.org/10.1037/0033-2909.86.5.889

Mulligan, J. (2015). Looking within and beyond the geometry curriculum: connecting spatial reasoning to mathematics learning. In *ZDM Mathematics Education*. https://doi.org/10.1007/s11858-015-0696-1

Nagy-Kondor, R. (2016). Spatial ability: Measurement and development. In *Visual-spatial Ability in STEM Education: Transforming Research into Practice*. https://doi.org/10.1007/978-3-319-44385-0_3

NCTM. (2000). Principles and Standards for

School Mathematics Overview. *Journal of Equine Veterinary Science*.

Ramful, A., Ho, S. Y., & Lowrie, T. (2015). Visual and analytical strategies in spatial visualisation: perspectives from bilateral symmetry and reflection. *Mathematics Education Research Journal*. https://doi.org/10.1007/s13394-015-0144-0

Rittle-Johnson, B., Zippert, E. L., & Boice, K. L. (2019). The roles of patterning and spatial skills in early mathematics development. *Early Childhood Research Quarterly*. https://doi.org/10.1016/j.ecresq.2018.03.006

Subanji. 2013. Pembelajaran Matematika Kreatif dan Inovatif. Malang: UM Press.

Sujarwo, S & Oktaviana, R. (2017). Pengaruh warna terhadap *short-term memory* pada siswa kelas VII SMPN 37 Palembang. *Psikis*

Torre Cantero, J., Saorín Pérez, J., Melián Díaz, D., & Meier, C. (2015). STELLA 3D: Introducing art and creativity in engineering graphics education. *The International journal of engineering education*.

Uttal, D. H., Meadow, N. G., Tipton, E., Hand, L. L., Alden, A. R., Warren, C., & Newcombe, N. S. (2013). The malleability of spatial skills: A meta-analysis of training studies. *Psychological Bulletin*. https://doi.org/10.1037/a0028446

Wakabayashi, Y., & Ishikawa, T. (2011). Spatial thinking in geographic information science: A review of past studies and prospects for the future. *Procedia - Social and Behavioral Sciences*. https://doi.org/10.1016/j.sbspro.2011.07.031

Walle, J. Van de. (2004). Geometric thinking and geometric concepts. In *Elementary and Middle school mathematics: Teaching developmentally.*

Wang, L., & Carr, M. (2014). Working Memory and Strategy Use Contribute to Gender Differences in Spatial Ability. *Educational Psychologist*. https://doi.org/10.1080/00461520.2014.960568

Wichmann, F. A., Sharpe, L. T. & Gegenfurtner, K. R. (2002). The contributions of color to recognition memory for natural scenes. *J Exp Psychol Learn*, *28*. Accessed on December 20, 2020 from https://pubmed.ncbi.nlm.nih.gov/12018503/

Wulandari, S., Sa'dijah, C., As'ari, A.R., Sulandra, & I.M., 2019. *Spatial Representation on Geometry*. International Journal of Scientific & Tecnology Research Volume 8, Issue 12

Yilmaz, H. B. (2009). On the development and measurement of spatial ability. *International Electronic Journal of Elementary Education*.