SPATIAL ABILITY AS A BASED ON SEARCHING OF PROBLEM-SOLVING ABILITY IN ADVANCED CALCULUS LECTURING AT UNNES

By: [1]Emi Pujiastuti and [1]Mulyono
Lecturers of Mathematics Department – Semarang State University (Unnes)
Contact Person: emipujiunnes@gmail.com

ABSTRACT

Spatial ability is indispensable in solving the problems associated with Advanced Calculus Course. The issue, whether geometric spatial ability does have a role to enhance the problem solving abilities of the students on the material of Dual Integral?To answer these problems have been conducted a qualitative research on the subject of research, namely students of Mathematics Education of Semarang State University (Unnes) who took a course Advanced Calculus. The results of this research revealed that the ability of problem solving in Advanced Calculus aspecially Dual Integral material requires a good geometric spatial ability. The cause, the problem solving abilities in Advanced Calculus aspecially Dual Integral material require geometric figures and involves many branches of mathematics. Searching a student's ability to solve problems has been preceded by analyzing the geometric spatial ability. Thus, the search problem-solving abilities of students at Dual Integral material can be more comprehensive, holistic, and intact.

Keywords: *Spatial, Problem Solving, Advanced Calculus*

A. Introduction

Background

Spatial ability is indispensable in solving the problems associated with Advanced Calculus Course. Alias, Black, and Gray (2002), stated that the ability of spatial visualization becomes an essential tool for the success of students in studying some subjects such as calculus or other branches of mathematics. Problems in Advanced Calculus course is quite complex, especially material related to Dual Integral. In solve the problems Dual Integral, often accompanied by pictures of geometric as supporters.

Error in the reading of figures, can result the student fails in solving the problem. The ability to draw the Space Geometry, read the figure, and interpret the figure, often called spatial ability. This Advanced Calculus course requires a range of prerequisite subjects as supporters. The material prerequisites include Calculus I, Calculus II, Elementary Algebra, Space Geometry, and Plane Geometry.

In addition, problem-solving skills of students need to be observed and traced, because this capability is needed by students in order to implement the process of transferable from mathematical mindset to be used in the practice of everyday life.

Because of the ability of problem solving in Advanced Calculus aspecially Dual Integral materials require geometric figures, then searching of the student's ability to solve problems should be preceded by analyzing the geometric spatial ability.

Thus, it is expected that the searching of problem-solving abilities of students at Dual Integral material can be more comprehensive, comprehensive, and intact. Hopefully, the results of research in uncovering spatial ability is the first step to understand the mindset of Mathematics Education Students in solving the problems associated with Advanced Calculus courses.

Problems

The problems that will be studied and solved through qualitative research is as follows. By the process of analyzing will be sought whether a geometric spatial ability has a role to improve problem-solving abilities of the students on the material of Dual Integral? The problem, broken down into sub-subproblems as follows. (1) Through the process of analyzing, how far the quality level of geometric spatial ability students of Mathematics Education of Semarang State University (Unnes)? (2) Through the process of analyzing, whether geometric spatial ability students of Mathematics Education of Unnes sufficient to support the ability to solve problems in Advanced Calculus? (3) Through the search process qualitatively, how the problem-solving abilities of the students in Dual Integral material terms of spatial abilities?

Research Purposes

Research purposes are: (1) through the process of analyzing will be found the quality level geometric spatial ability students of Mathematics Education of Unnes; (2) through the process of analyzing, it will be known whether the geometric spatial ability students of Mathematics Education of Unnes sufficient to support the ability to solve problems in Advanced Calculus; (3) through the search process qualitatively, will be found if the problem solving abilities of the students in the Dual Integral material can be viewed from the spatial abilities.

B. Study of Theory

1. Geometric Spatial Ability

Geometric spatial ability is the ability to read, understand, and interpret geometric figures correctly. Expressed also by Marunić & Glažar (2014) and Fadillioglu & Askar (1999) wrote that the ability to maintain the position of the solid figure in accordance with reality, able to retrieve or change the visual image was defined / given correctly called as geometric spatial abilities. Geometric spatial ability of students is the power or force of students to be able to observe and understand every meaning of geometric figures, either one-dimensional, two-dimensional, or three-dimensional.

Guzel and Sener (2009), stated that spatial ability was an important factor for achieving high achievement, particularly in the field of geometry. It said further that this spatial abilities could enhance students' understanding in reading a symbol and image geometry. In fact, Saori, Torre, et al (2012) stated that within fifty last, spatial ability students is important, accepted, and the increasing recognition that the ability spatial needed to understand the science of engineering, technology, and mathematics, as well as useful in almost every other aspects of life. Described by Ozdemir and Yildiz (2014) that the students' high spatial ability can improve their reasoning skills.

Geometric spatial ability of students is very necessary, if the student will solve the problems related to the Dual Integral matter. Students should be able to find the elements that are known in the matter, capable of designing geometric images, and can determine its meaning and then can then use the geometric figures to solve the problems in Dual Integral.

If the student fails to design a geometric figure, can not draw a geometric shape, does not know the meaning of geometric drawings, then the student will fail to use the geometric figures to solve the problem or problems in Dual Integral of which must be completed. Muslim, Ariffin, and Din (2013) wrote that the knowledge of the spatial abilities of the students helps lecturer to organize a way to explain a material that suitable with student's power.

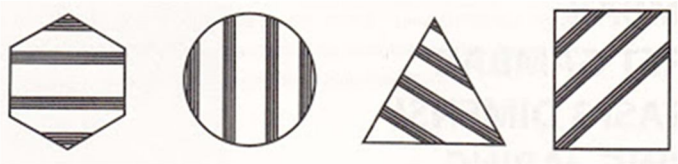
In this preliminary study, spatial ability which will be revealed include Spatial Ability Basic/General, Spatial Ability on plane geometry, and Spatial Ability on solid geometry. The third spatial ability which will be revealed this in accordance with the opinion of Barnea, N. (2000) and Marunić, G and Glažar, V. (2014), three of them need to load the

three indicators, which includes indicators: (1) spatial orientation, (2) spatial visualization, and (3) spatial relations.

Spatial orientation is as the ability to imagine what is presented/ represented can be seen in a different perspective.

Example:

Which geometrical figure below that has a different image patterns?

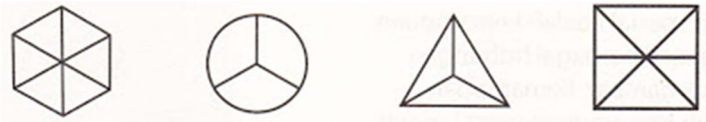


There is a possibility, someone will see the difference of patterns in the figures above through the perspective of each. The key answer is in the figure at the right. Look at the picture that in every rise and shaded by four lines adjacent to each other and shape rightmost figure has only 3 lines.

Spatial visualization is the ability to observe or distinguish the object from two or three dimensions accurately through representation.

Example:

Look at the plane figures below. Which pattern was different?



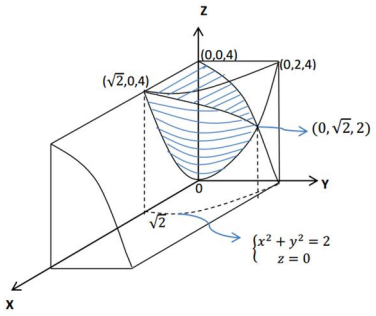
A B C D

The expected answer above observation is D, due to new geometrical shapes formed by the lines do not have the same area.

Spatial relation is an ability to visualize the effects of an operation or to be related/applied to a settlement of a matter.

Example:

In the picture below is given $\frac{1}{4}$ parts of the object.



A. Paraboloid $z = 2x^2 + y^2$ and parabolic cylinder $z = 4 - y^2$.
B. Paraboloid $z = x^2 + y^2$ and parabolic cylinder $z = 4 - y^2$.
C. Paraboloid $z = 4x^2 + y^2$ and parabolic cylinder $z = 4 - y^2$.
D. Paraboloid $z = 2x^2 + y^2$ and parabolic cylinder $z = 6 - y^2$.

The expected answer is A. The spatial ability has already associated with a person's ability to draw the paraboloid $z = 2x^2 + y^2$ and the parabolic cylinder $z = 4 - y^2$.

Thus, Geometric spatial ability of student is needed, if the student will solve the problems related to the material of Dual Integral. Students should be able to find the elements that are known in the problem, capable of designing a geometric figure. Spatial ability becomes supporter.

2. The ability of Problem-Solving

According to Wiederhold (2001), problem-solving abilities required by each student and problem-solving ability ia a high-level thinking skills. One question, can not always be used as a tool to uncover the problem-solving abilities. If a problem has been trained to students, and students already know the algorithm to solve the problem, and on the other day about which type (for example, the numbers just changed course) given back to the students, then the new problem is clearly not applicable to reveal the problem-solving abilities for students.

According to Zaini (2002) also Suyitno (2006), a problem/task could be used as a tool to reveal the ability of a problem for the student if: (1) the material prerequisites to answer the question that have been taught by the lecturer/teacher; (2) algorithm to solve a problem that has not been given to the students; (3) the solution of the question is reached by students; (4) students willing to do/answer the question.

In general, the strategy to work on the problems that are characteristically problem-solving using Polya's step. According to Polya (1971) and Herman (2000), the solution about problem solving includes a four-step phase of completion, namely: (1) understanding

the problem, (2) planning processes, (3) solving the problem according to plan, and (4) checking all the measures which have been undertaken. Burns (2002), in one of his writings stated that the students will feel more confident if they can find their own settlement questions given by the teacher/lecturer to him/her.

3. Spatial Ability in Dual Integral

The following will be presented examples of problems whose solution dual integral requires a geometric spatial ability and mathematical connections. Problem is taken from Baisuni (1986).

Example 1:

Calculate the volume of ellipsoid $\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} = 1$.

Solution:

a. Look at the figure I below:

In the picture given $\frac{1}{8}$ parts of ellipsoid.

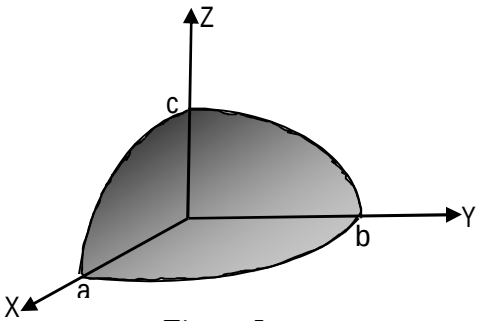
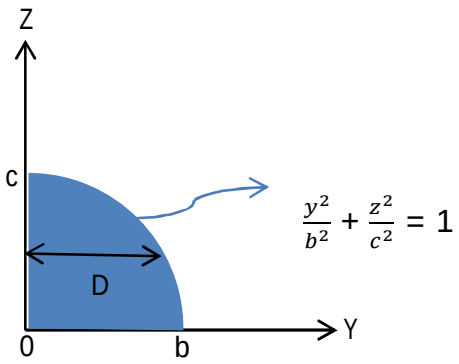


Figure I

b. If projection D of I on YOZ is $\frac{1}{4}$ circles then if brought to R^2 , it picture as follows:



Area D is partitioned to Z axis, then the area of integration are:

$$D = \left\{ (y,z) \middle| 0 \le z \le c, 0 \le y \le b\sqrt{1-\frac{z^2}{c^2}} \right\}$$

So, from the picture of ellipsoid in R^3, integration boundary is

$$I = \left\{ (x,y,z) \middle| 0 \le x \le a\sqrt{1-\frac{y^2}{b^2}-\frac{z^2}{c^2}}, 0 \le y \le b\sqrt{1-\frac{z^2}{c^2}}, 0 \le z \le c \right\}$$

c.Then the volume of Ellipsoid I is

$$I = 8\int_0^c \int_0^{b\sqrt{1-(\frac{z}{c})^2}} \int_0^{a\sqrt{1-(\frac{y}{b})^2-(\frac{z}{c})^2}} dx\,dy\,dz$$

$$I = 8\int_0^c \int_0^{b\sqrt{1-(\frac{z}{c})^2}} a\sqrt{1-(\frac{y}{b})^2-(\frac{z}{c})^2}\; dy\,dz$$

$$I = 8\int_0^c b[\frac{y}{2b}\sqrt{1-(\frac{y}{b})^2-(\frac{z}{c})^2} + \frac{1-(z/c)^2}{2}\, arc\sin\frac{y}{b\sqrt{1-(\frac{z}{c})^2}}]\Bigg|_0^{b\sqrt{1-(\frac{z}{c})^2}} dz$$

$$I = 2\pi ab\int_0^c (1-\frac{z^2}{c^2})\,dz$$

$$I = 2\pi ab\ (z-\frac{z^3}{3c^2})\Big]_0^c$$

$$I = 2\pi ab\ (\frac{2c}{3})$$

$$I = \frac{4\pi}{3}abc$$

So, the volume of ellipsoid $\frac{x^2}{a^2}+\frac{y^2}{b^2}+\frac{z^2}{c^2}=1$ is $I = \frac{4\pi}{3}abc$ **unit volume.**

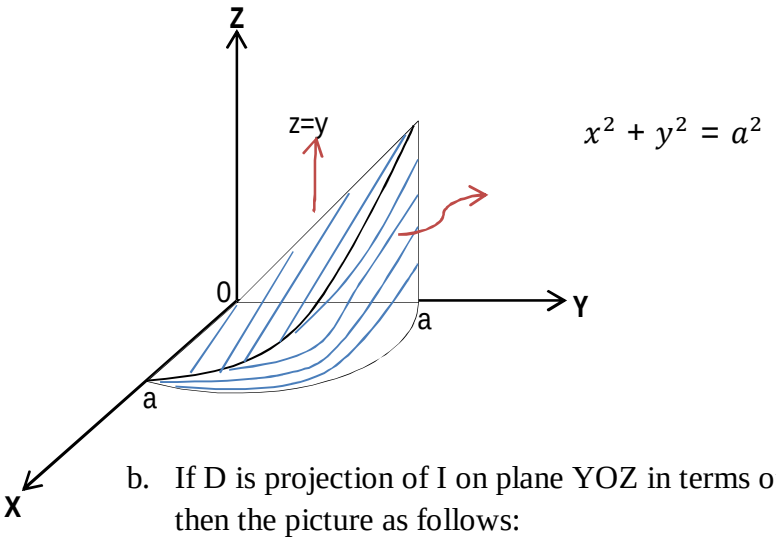
Example 2:

Calculate the volumeof object is limited by a cylinder $x^2 + y^2 = a^2$, planes $z = y$ and $z = 0$.

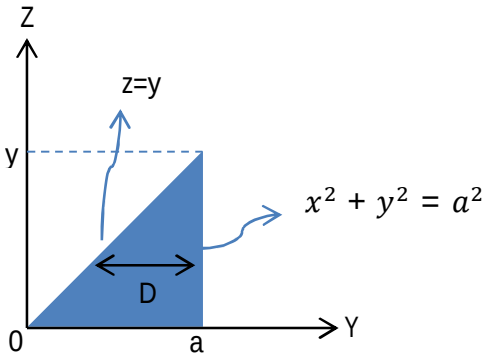
Solution:

a. Figure of objects I happens.

In the picture given $\frac{1}{4}$ parts of the object.



b. If D is projection of I on plane YOZ in terms of a triangle then if is brought into R^2 then the picture as follows:



The area D is partitioned to Z axis, then the area of integration are:

$$D = \left\{(y,z) \middle| 0 \le z \le y, 0 \le y \le \sqrt{a^2 - x^2}\right\}$$

So, view the elliptical picture in R^3, integration boundary is

$$I = \left\{(x,y,z) \middle| 0 \le x \le a, 0 \le y \le \sqrt{a^2 - x^2}, 0 \le z \le y\right\}$$

c. Then the volume of the cylinder I is

$$I = 4\int_0^a \int_0^{\sqrt{a^2-x^2}} \int_0^y dz\, dy\, dx$$

$$= 4\int_0^a \int_0^{\sqrt{a^2-x^2}} \int_0^y y\, dy\, dx$$

$= 2\int_0^a y^2 \Big|_0^{\sqrt{a^2-x^2}} dx$

$= 2\int_0^a a^2 - x^2\, dx$

$I = 2\left(a^2x - \frac{1}{3}x^3\right)\Big|_0^a = \frac{4}{3}a^3$

So the volume of the object bounded by the cylinder $x^2 + y^2 = a^2$, areas $z = y$ and $z = 0$ is $\frac{4}{3}a^3$ unit volume.

Based on exposure of the three examples above, the ability of spatial geometric, mathematical connection ability, and problem-solving strategies need to be nurtured on the students themselves.

C. Method of Research

Research subject

The research subjects are students of Mathematics Education Study Program of Semarang State University (Unnes) who took a course of Advanced Calculus. Furthermore, the position of the students will be ranked based on the level of academic achievement and further differentiated into three major groups namely the upper/clever, middle group/moderate, and lower group/less. Each group was taken two students to be analyzed and traced according to the research objectives to be achieved.

Time Research

Research time is designed to begin at the beginning of the odd semester, the semester where Advanced Calculus course appears in Mathematics Education Study Program of Unnes.

Qualitative Data Analysis

The analysis of the data in this qualitative research using rules Matthew B. Miles and A. Michael Huberman. Miles and Huberman as translated by Rohidi (1992), suggested that activity in the qualitative research data analysis performed interactively and lasted continuously until complete, so that the data is complete.

The size of the data completeness is characterized by not obtaining again of data or new information as appropriate. Activity in the analysis of the data include: reduction of data, presentation of data, interpretation of the data (data interpretation), conclusion drawing/verification.

1) Data reduction may be interpreted narrowly as a data reduction process, but in a broader sense is a process of refinement of data, either a reduction of the data is less necessary and irrelevant, or additions to the data that it is still lacking.
2) Presentation of data is the process of gathering information, sorted by categories or groupings required.
3) Data interpretation is the process of understanding the meaning of a set of data that has been presented, in a form that does not just look at what is written, but rather to understand or interpret as to what is implied in the data that has been presented.
4) Drawing conclusions/verification is the process of formulating the meaning of the results expressed by the sentences short, compact, and easily understood, and is done by repeatedly reviewing the correctness of the inference, particularly the relevance and consistency of the title, objectives, and the formulating problems.

Data Collection Technique

1) Quantitative data drawn from the results of tests to determine the position of students based on academic achievement.
2) The qualitative data taken from field notes or daily journal during observing the course, the results/products student test based on the analysis of geometric spatial ability and mathematics connection capabilities, and the results of interviews that relevant to the problem-solving abilities, between researcher and students the subject of research.
3) Triangulation/comparing all the findings in order to draw valid conclusions in accordance with the research purposes and problem formulation.

Criteria for Successful

The criteria/indicators of the success of this research are the attainment of the objectives of this research are as follows.

1) Found the quality level of geometric spatial ability students of Mathematics Education of Unnes.
2) Known whether the geometric spatial ability of Mathematics Education students of Unnes sufficient to support the ability to solve problems in Advanced Calculus.
3) Found either problem-solving abilities of the students in the Dual Integral material can be viewed from the spatial abilities.

D. Results and Discussion

Research Result

Based on Preliminary research in the classroom, the research results are as follows.

1) Category or Quality Level of Geometric Spatial Ability

Based on the results of an assessment of the ability of spatial geometry, the result level of quality as follows.

Table 1: Category of Geometric Spatial Ability

No.	Category or Quality Level	Number of student
1	Very good	6
2	Good	10
3	Enough	17
4	Less	1
5	Very less	0
The sum of students		34

2) Score of Problem-Solving Ability

Based on the results of tests on Problem-Solving Ability with Dual Integral material, obtained the following results.

Table 2: Skor of Problem-solving Ability

No.	Interval of Skor (x)	Number of student
1	$86 \leq x \leq 100$	5
2	$81 \leq x < 86$	11
3	$71 \leq x < 81$	15
4	$61 \leq x < 71$	2
5	$x < 61$	1
The sum of students		33

Furthermore, of the 34 students were divided into 3 groups based on the rank ordering of the values obtained from the test results about the ability of Dual Integral. Top selected group of 11 students, the Middle group selected 12 students, and 11 students were taken Bottom group. Each group was taken two students who will be observed and interviewed in depth. The test results of spatial ability, problem-solving abilities, observation, and interviews were then compared through triangulation process.

3) The results of triangulation process

Through the process of analyzing of triangulation process, it is known that the geometric spatial ability students of Mathematics Education of Unnes sufficient to support the ability to solve problems in Advanced Calculus. Based on the assessment and interview the results are as follows. The geometric spatial ability students of Mathematics Education of Unnes is sufficient to support the ability to solve problems in Advanced Calculus. Students who have high levels in geometric spatial ability, also has the ability to solve problems in Advanced Calculus is also high. And vice versa.

4) Furthermore, through the searching of process qualitatively, it has been found that the problem-solving skills of the students in the Dual Integral material can be viewed from the geometric spatial abilities.

Discussion

Problem-solving abilities in Advanced Calculus requires a good geometric spatial ability. Through analyzing the process has been found to the quality level of geometric spatial ability students of Mathematics Education of Unnes. From the analysis, the level of quality of geometric spatial ability students of Mathematics Education of Unnes, the very good category was 6 students, the good category was 10 students, the enough category was 17 students, the category of less was 1 student, and no students in very less. These findings are useful to map the ability of students of Mathematics Education of Unnes especially in exposing the geometric spatial ability.

Based on the research results, it is true that the level of quality of a good geometric spatial ability is needed to support the ability to solve problems in Advanced Calculus. It has been proven that through the process of analyzing, it has been known that the geometric spatial ability students of Mathematics Education of Unnes sufficient to support the ability to solve problems in Advanced Calculus.

Based on the assessment and interview the result is that the geometric spatial ability students of Mathematics Education of Unnes is sufficient to support the ability to solve problems in Advanced Calculus. Students who have high levels of high geometric spatial ability, also has the ability to solve problems in Advanced Calculus is also high. And vice versa.

Through the searching of process qualitatively, it has been found that the problem-solving abiities of the students in the material can be viewed from the Advanced Integral spatial abilities. As the results of the second study, the students who have the ability to solve problems in Advanced Calculus also have a high level of geometric high spatial ability. Conversely, students who have the ability to solve problems in Advanced Calculus being also has the ability level of spatial geometric being anyway.

Finally, students who have the ability to solve problems in Advanced Calculus less also had higher levels of geometric spatial abilities are less well. Thus, it can be concluded that before skilled students solve problems in Advanced Calculus, students should also be trained anyway geometric spatial ability.

E. *Conclusions*

Based on the results of research and discussion, it can be concluded as follows.

1. Through analyzing the process has been found to the quality level of geometric spatial ability students of Mathematics Education of Unnes.
2. Through the process of analyzing, it has been known that the geometric spatial ability students of Mathematics Education Unnes sufficient to support the ability to solve problems in Advanced Calculus.
3. Through the searching of process qualitatively, it has been found that the problem-solving abilities of the students in the Advanced Integral material can be viewed from the geometric spatial abilities.

F. References

Alias, M., Black, T., & Gray, D. 2002. Effect of Instructions on Spatial Visualisation Ability on Civil Engineering Students. *International Education Journal Vol 3, No 1*. Available at http://iej.cjb.net.

Baisuni, M. Hasyim. 1986. *Kalkulus*. Jakarta: Universitas Indonesia - UI-Press.

Barnea, N. (2000). Teaching and Learning About Chemistry and Modelling With a Computer Managed Modelling System. *Developing Models in Science Education*, Kluwer Academic, Dordrecht, 2000, 307–324.

Burns, Marilyn (Editor Neil Davidson). 2002. *The Math Solution: Using Groups of Four – Cooperative Learning in Mathematics.* California: Addison Wesley.

Delialioglu, Ömer and Aşkar, Petek. 1999. Contribution of students' mathematical skills and spatial Abillty to achievement in secondary school physics. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi /6-/7* : 34 – 39.

Guzel, N., & Sener, E. 2009. High School Students' Spatial Ability and Creativity in Geometry. *Procedia – Social and Behavioral Sciences Volume 1 pages 1763-1766.* Elsevier. Available at www.sciencedirect.com.

Herman, Tatang. 2000. Strategi Pemecahan Masalah (Problem-Solving) dalam Pembelajaran Matematika. *Paper is presented in Assisted Activity of Madrasah Ibtidaiyah and Tsanawiyah Teachers of West Java 28 September to 3 October 2000.* Collaboratin of ITB and Depag RI.

Marunić . G and V. Glažar. V. 2014. Improvement and assessment of spatial ability in Engineering education. *Engineering Review, Vol. 34, Issue 2, 139-150, 2014.*

Musliman, R., Ariffin, S., & Din, R. 2013. Assessing Students' Spatial Intelligence for Literacy and Numeracy Skills. *Procedia – Social and Behavioral Sciences Volume 90 pages 695-701.* Elsevier. Available at www.sciencedirect.com.

Ozdemir, A., & Yildiz, S. 2015. The Examination of Elementary Mathematics Pre-Service Teachers' Spatial Abilities. *Procedia – Social and Behavioral Sciences Volume 174 pages 594-601.* Elsevier. Availabel at www.sciencedirect.com.

Polya, G. 1971. *How to Solve It: A New Aspect of Mathematics Method*. New Jersey: Princeton University Press.

Rohidi, Tjetjep Rohendi, 1992. *Analisis Data Kualitatif.* Jakarta: UI Press.

Saorin, J., dkk. 2013. Spatial Training Using Digital Tablets. *Procedia – Social and Behavioral Sciences Volume 93 pages 1593-1597.* Elsevier. Available at www.sciencedirect.com.

Suyitno, Amin. 2006. *Dasar-Dasar dan Proses Pembelajaran Matematika.* Semarang: FMIPA UNNES.

Wiederhold, Chuck W. 1998. *Cooperative Learning & Higher Level Thinking.* San Clemente: Kagan Cooperatine Learning.

Zaini, Hisyam. 2002. *Strategi Pembelajaran di Perguruan Tinggi.* Yogyakarta: CTSD (Center for Teaching Staff Development).