EduMa
MATHEMATICS EDUCATION LEARNING AND TEACHING
article link: https://syekhnurjati.ac.id/jurnal/index.php/eduma/eduma/article/view/8518

Development of Geometry Test Based on Van Hiele's Theory in Exploration Profile of Student's Spatial Reasoning Ability Level

Komala[1], Budi Manfaat[2], Arif Abdul Haqq[3*]

[1, 2 ,3] Departement of Mathematics Education, IAIN Syekh Nurjati Cirebon

* Corresponding author: Sunyaragi , Cirebon, Jawa Barat, 45132, Indonesia. e-mail addresses: mr.haqq@gmail.com

a r t i c l e i n f o	a b s t r a c t
  	Assessment of geometry learning should encourage students to have spatial reasoning abilities. This type of study is research and development to develop a geometry test instrument with Van Hiele's level of thinking to measure students' spatial reasoning abilities. This research and development aim to obtain a valid and reliable test instrument for spatial reasoning abilities. This test has been declared content validity through expert judgment techniques and has been declared linguistically correct by linguists. Based on the results of the field test, the test instrument has a reliability of 0.89. The developed test instrument has a pretty good average distinguishing power estimate. The results of the difficulty level of the developed test are 12.5% items have a very easy, 25% easy, 37.5% moderate, and 25% difficult. The results of the measurement of students' spatial reasoning ability obtained that 25% of students had low spatial reasoning abilities (Plane), 60.71% in the medium category (Fuzzy), and 14.29% in the high category (Spatial).

INTRODUCTION

Learning in schools must encourage students' abilities based on the learning objectives to be achieved. In the process of learning mathematics, geometry is one of the essential materials and unique difficulty (Haqq, 2020; Haqq et al., 2018, 2019; Sakinah et al., 2019). Geometry material is studied from elementary school to college level. Ristontowi (2013) explains that one of the standards for studying geometry is for children to have visualization skills, spatial reasoning, and geometry modeling to solve existing problems. The material of spatial geometry is one of the subjects in which it requires spatial reasoning. The level of thinking development in learning geometry, according to Van Hiele's theory, is divided into five stages. The first stage is visualization; the second stage is analysis. The third stage is abstraction or informal deduction. The fourth stage is formal deduction, and the highest stage is the rigor level.

A student who can recognize the name of a shape and recognize its overall shape, then the student is at level 0 or the level of visualization. At this stage, students can identify, compare, name and operate geometric images but only visual characteristics. When students can recognize a shape based on their factors, then the student has reached level 1 or level of analysis. Students at level 1 are able to analyze and observe the properties that exist in these shapes. Level 2, or abstraction in Van Hiele's level of thinking, is also called the relational level, where at this level, students are able to organize logical thinking and can understand the relationship between the characteristics of one spatial structure and another. By the time the student is able to understand the role of understanding, axioms as well as definitions and theorems, then he has reached level 3 or the level of deduction. Students at level 3 can think deductively as well as mathematics which is a deductive science. The highest level is level 4 or rigor. Students at this stage are able to do formal reasoning. Students who reach this level are able to understand the existence of a proposition or postulate.

According to Van Hiele's theory, in studying geometry, all children go through these stages in the same order, and it is impossible for any level to be skipped. However, between one student and another student can not be equated when starting to enter a new level. Razak, & Sutrisno (2017) explained that each level of Van Hiele's thinking has certain characteristics that cause students to differ in understanding and solving geometric problems. Each stage in Van Hiele's theory shows the aspects of students' thinking processes in learning geometry. The quality of student knowledge is not determined by the accumulation of knowledge but is more determined by the thinking process used (Abdussakir, 2012). The application of the Van Hiele model is practical for improving the quality of students' thinking. Van Hiele's level of thinking describes student achievement in learning geometry (Ana & Ana, 2016; Muchsin et al., 2018; Tajik & Maqsood, 2019).

Clements & Battista (1992) explained that spatial reasoning ability is the ability with one's cognitive processes in representing and manipulating spatial objects and their relationships and transformations. Spatial reasoning abilities include aspects of spatial orientation and spatial visualization. Spatial orientation is related to a person's ability to understand the position of an object based on the direction of view; meanwhile, spatial visualization ability focuses on the process of identifying and depicting shapes and shapes. According to Williams, Gero, Lee, & Paretti (2010), spatial reasoning ability is the ability

to process and form ideas through spatial relationships between objects to find solutions to a problem. They are defined spatial reasoning as the process of finding a solution to a spatial problem by recognizing and manipulating shapes. From this definition, it can be understood that spatial reasoning ability is the ability to obtain a conclusion through one's cognitive processes in imagining, representing, and transforming visual information in a spatial context.

Students need spatial reasoning skills to face various problems and challenges of the 21st century. The importance of spatial reasoning is also explained by Astuti (2016)that spatial reasoning abilities are very useful in the fields of science, technology, engineering, and mathematics, which are always used in various life contexts. Because of the importance of spatial reasoning in everyday life, it is important for students to hone their spatial reasoning skills. Spatial ability and geometry skills decrease when students enter high school and college (Aliman et al., 2019). This can be influenced by geometry learning factors, as revealed by Ardhi Prabowo (2011) that in geometry material, learning is focused on students' abilities which are limited to definitions and solving problems in books without understanding the concept in depth. This opinion is in line with the opinion of Rikanah & Winarso (2016), which states that students sometimes find it difficult to illustrate the shape of a three-dimensional space that is hollow in it. These statements are reinforced by what Risma, Putri, & Hartono (2013)stated that students are always forced to understand the representation of two-dimensional objects from solid objects, which are sometimes isometric images or horizontal images, so students need to have good visualization skills.

According to Afriyanti, Wardono, & Kartono (2018), students are not familiar with being given questions with problems that require logical and applicable thinking. Most teachers only take questions from books without analyzing the questions first, so it is not known whether the items are good or not and cannot measure the competence of students towards the certain subject matter. The tests are commonly used generally use teacher-made tests sourced from textbooks. The test is rarely analyzed beforehand or developed according to what it is intended to measure. Assessment of geometry learning should encourage students to have spatial reasoning abilities. Spatial reasoning test instruments should be designed according to the objectives of learning geometry, namely to develop logical thinking skills, to be able to develop spatial intuition about the real world, to impart the knowledge needed for advanced mathematics, and to teach how to read and interpret mathematical arguments. However, there are not many test instruments that can measure students' spatial reasoning abilities, so they need to be developed. The test instrument developed in this study focused on the geometry of space. The developed test refers to Van Hiele's level of thinking but is only developed to level 3 (formal deduction). It considers that the development of the test is intended for class XII and has not yet reached level 4 (Rigor). The purpose of this study was to obtain a valid and reliable test instrument for spatial reasoning abilities and to find out the profile of the level of spatial reasoning ability of class XII science students.

Tian & Huang (2009) categorize the level of spatial reasoning ability into three levels, namely high (spatial), medium (fuzzy) and low (plane). The three levels of spatial reasoning ability can be described as follows:
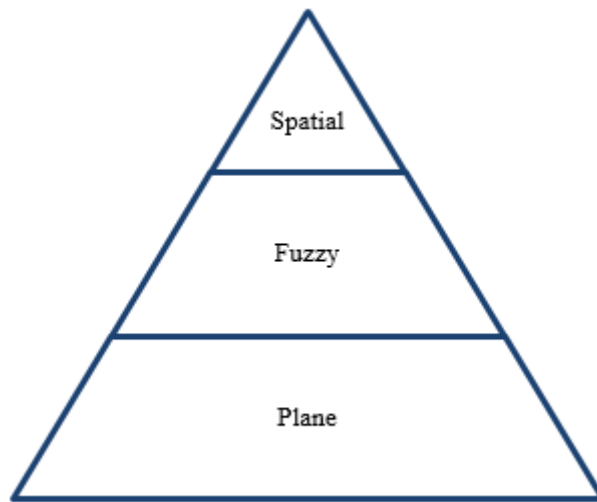
Figure 1.
Category Level of Spatial Reasoning Ability

1) Spatial: Students can convert two-dimensional images into three-dimensional objects so that there is a correct relationship and able to solve spatial problems correctly accompanied by appropriate explanations.

2) Fuzzy: Students are weak in converting images of two-dimensional shapes into three-dimensional objects so that students can solve spatial problems correctly but are not accompanied by proper explanations.

3) Plane: Students cannot convert two-dimensional images into three-dimensional objects, so students cannot solve spatial problems correctly and are not accompanied by proper explanations.

METHOD

This study was developed based on the research and development method, which is a research process for developing and validating data on educational products. The subjects of the research trial were students of class XII majoring in science at MA Negeri 1 Kuningan. The development procedure used adopts the development model of Azwar (2015). The procedure for developing this research is presented in the following figure:
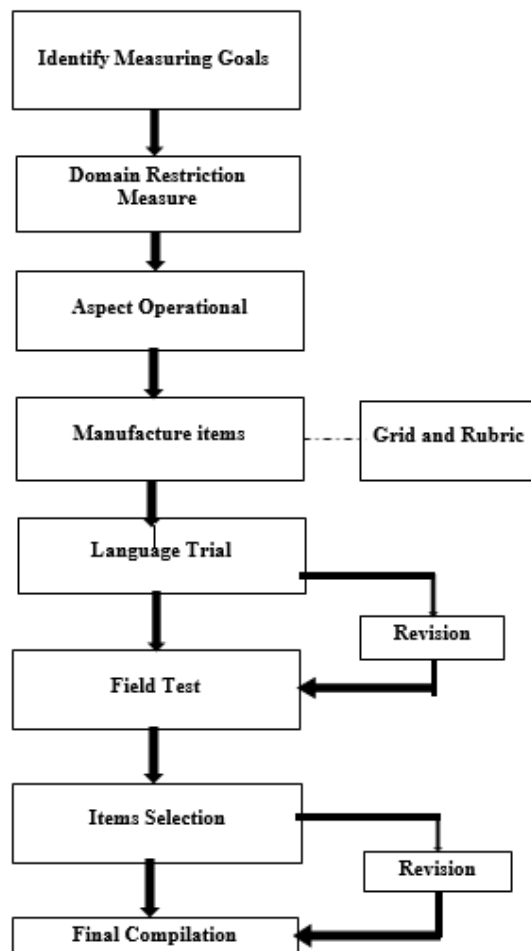
Figure 2.
Development Procedure Flow

The initial step in the preparation of the instrument starts from the identification stage of measuring objectives. At this stage, the researcher chooses a definition and explores various theories relevant to the research. The aspect that will be measured is spatial reasoning ability, and the measuring domain is limited to the cognitive aspect. At the operationalization stage of the aspect, the conceptual definitions of the variables are operationalized into operational definitions in order to facilitate measurement. Operational definitions are formulated into indicators that represent aspects that must be revealed by students. The set of indicators is stated in the form of a grid. After the grid is made, the next step is to write the questions. The items developed were eight items representing each Van Hiele level from level 0 to level 3. The items that had been made were then validated by experts (Expert Judgment) with content and language validation. After validation, the next stage is a field test to determine the reliability, estimation of distinguishing power, and the difficulty index of the questions. If the results of the analysis have been met according to the criteria, then the questions are made in final form. The form of the final compilation of test instruments consists of 4 questions.

Data analysis techniques are through expert judgment, tests, and questionnaires. The expert judgment technique was carried out to validate the items in terms of content and language. The test is given to students of class XII IPA to determine the quality of the test and the level profile of students' spatial reasoning abilities. Questionnaires are used to test the readability of items. The results of the assessment of expert judgment were

analyzed using the Content Validity Ratio (CVR) formula from Lawshe (1975). The CVR formula used is as follows.

$$CVR = \frac{2n_e}{N} - 1 \qquad (1)$$

Keterangan:
n_e : Number of experts who gave a rating of 3
N : Total of all expert team
Amount After each item is identified using the CVR, then the Content Validity Index (CVI) is calculated as the average validity of the questions received. CVI is formulated as follows (Hendryadi, 2017).

$$CVI = \frac{\sum CVR}{\text{Number of items accepted}} \qquad (2)$$

The category of the results of the CVR and CVI calculations is in the form of a ratio of numbers 0-1, which can be seen in the following table.

Table 1.
CVI Calculation Result Category

Value	Category
$0 - 0,33$	Unsuitable
$0,34 - 0,67$	suitable
$0,68 - 1$	Very Suitable

Reliability estimates were analyzed using Cronbach's alpha formula.

$$r_{11} = \left(\frac{K}{(K-1)}\right)\left(1 - \frac{\sum \sigma_b^2}{\sigma_t^2}\right) \qquad (3)$$

The tests with high distinguishing power cannot measure students who master learning competencies. The distinguishing power of spatial reasoning ability test questions is calculated using the following formula:

$$DP = \frac{U - L}{Nup \times Max\ Score} \qquad (4)$$

A good test item is a test item that has a moderate level of difficulty, meaning that the question is neither too easy nor too difficult. The formula used to calculate the test difficulty index is:

$$DL = \frac{B}{N \times Max\ Score} \qquad (5)$$

The scoring criteria for students' spatial reasoning ability test questions use holistic scoring rubrics from Cai, Lane, and Jakabcsin (Anwar, 2014). The student scores that have been obtained are converted into grades in the following way.

$$X = \frac{Score\ obtained}{Total\ Score} \times 100\%$$ (6)

The scores obtained by the students were converted into a scoring table. This assessment uses the Norm Reference Assessment (NRA). The average score obtained by students from the rubric will be processed into grades with categories and into interval data with three categories. The category is based on the level of spatial reasoning ability according to Tian & Huang (2009), namely high (spatial), low (fuzzy), and low (plane). The reference for changing the score to a scale of 3 is as follows.
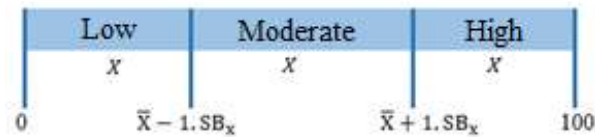

Figure 3.
Measurement result category

The framework of thought in this research can be depicted in Figure 4. as follows.
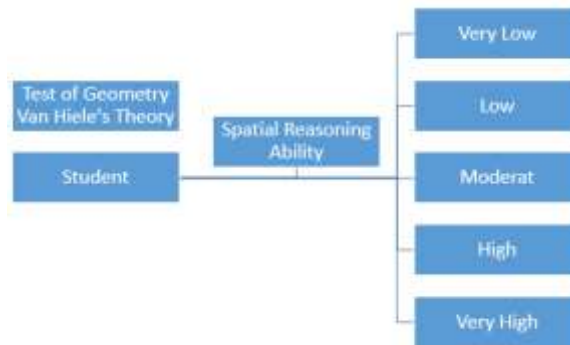

Figure 4.
Research and Development Thinking Framework

RESULTS AND DISCUSSION

Instrument Indicator

The instrument indicators and items developed were adapted to Van Hiele's level of thinking. Van Hiele's level of thinking was developed only up to level 3 (Formal Deduction) with the consideration that the research was carried out in class XII where students had not been able to reach level 4 (Rigor) of Van Hiele's level of thinking. The indicators of spatial reasoning ability used in developing test instruments are presented in the following table.

Table 2.

Spatial Reasoning Ability Indicator

Spatial Reasoning Ability Indicator	van Hiele's level of thinking	Question Number
Spatial Orientation	0 – 3 Level	1, 2, 3, 4, 5, 6
Spatial Visualisation		
Spatial Perception		
Spatial Relation	3th Level	7, 8
Mental Relation	4th Level	-

From the table above, the item indicators developed include spatial orientation, spatial visualization, spatial perception, and spatial relations with Van Hiele's level of thinking from level 0 to level 3. After compiling the distribution of spatial reasoning indicators with Van Hiele's thinking level, further items are developed. The questions are adjusted to the geometry learning indicators in class XII IPA.

Instrument Validity

The validity of the developed instrument is indicated by the validity of the content and language. Validity analysis was carried out based on the Content Validity Ratio (CVR) from the expert team. All items were declared to support load validity with a CVR value of 1. After obtaining the CVR value, the Content Validity Index (CVI) was calculated as the average validity of the questions received. The following is the result of the CVI calculation.

$$CVI = \frac{\sum CVR}{number\ of\ questions\ accepted}$$

$$CVI = \frac{8}{8} = 1$$

Based on the results of the CVI calculation, a CVI value of 1, means that the items written, in terms of content, are following the aspect to be measured. The correlation results of the items were analyzed using Anates Software V.4.0.5. The results of the correlation analysis of the items are presented in the following table.
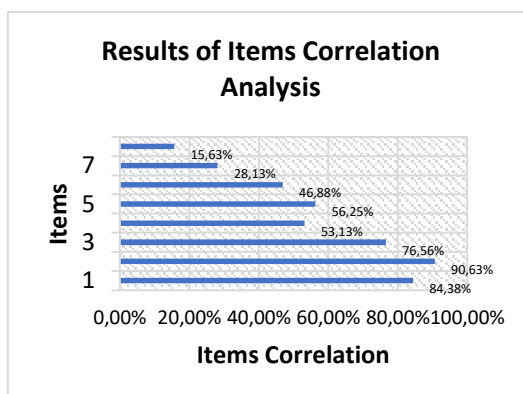

Figure 5.
Results of Item Correlation Analysis

The table above shows that there is 1 item (item number 2) that is not significant with a very low correlation number (0.201). This means that item number 2 has a very low estimate of distinguishing power. Five items have a significant item correlation, and two items are very significant. In order to make it easier to understand the correlation value of the question, the researcher presents it in the following pie chart.
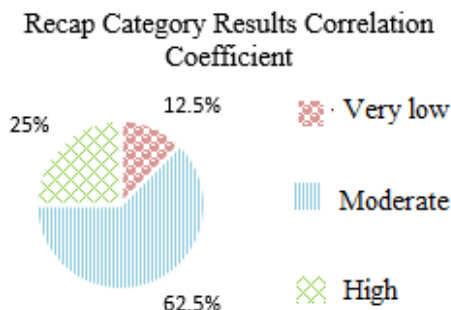

Figure 6.
Recap Category Results Correlation Coefficient

Reliability Instrumen

The reliability estimate from the results of a broad trial involving 30 students of class XII IPA 1 was calculated using Cronbach's alpha formula. The computation uses Anates Software V.4.0.5 with the following reliability test results.

Table 3.
Question Reliability Results

Average	Standard Deviation	KorelasiXY	Reliability
18,03	3,56	0,80	0,89

Based on the table above, it is known that the results of reliability calculations using Anates Software V.4.0.5 obtained a reliability coefficient of 0.89 with high criteria. This shows that the test instrument is said to be reliable, so there is no need for revision of the instrument according to the reliability test results. Thus, the test of spatial reasoning ability has constant consistency.

Estimation of Grain Distinguishinging Power

Distinguishinging power shows the relationship or correlation of each item with the test score. The distinguishing power of questions aims to distinguishing between high-ability students and low-ability students. The results of the calculation of th distinguishing power estimate are shown in the following table.
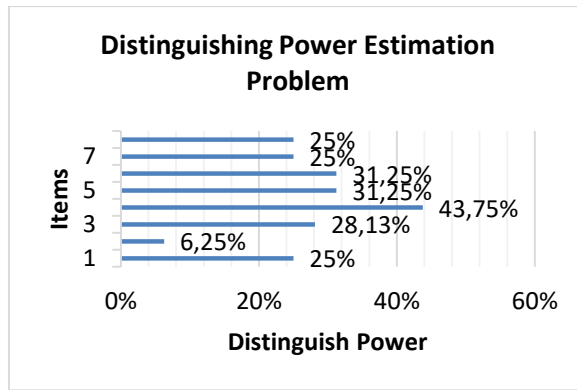
Figure 7.
Estimation of Distinguishing Power of Items

The estimated distinguishing power that has been analyzed, on average, is in the fairly good category. Only one item has a bad distinguishing power category, and one other item is included in the good distinguishing power category. The number of questions that fall into the category of insufficient, sufficient, and suitable distinguishing power is presented in the following pie chart
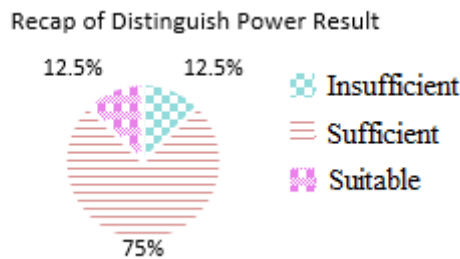

Figure 8.
Recap of Distinguishinging Power Results

Instrument Difficulty Index

Good items are items that are not too easy and not too difficult. In addition to analyzing the estimation of distinguishing power, the item difficulty index needs to be analyzed so that it is in accordance with the Van Hiele level used in this development. The results of the difficulty level of the test are as follows:
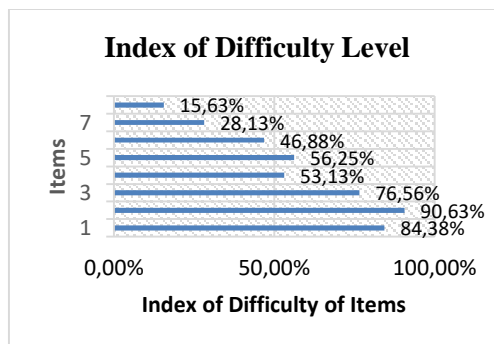

Figure 9.
Instrument Difficulty Index

92

Based on the table above, there is one question that is included in the easy category, namely item number 2, with a difficulty level of 90.63%. Two items are included in the easy category, namely items number 1 and 3, with a difficulty level of 84.38% and 76.56%, respectively. Furthermore, there are three items belonging to the medium category, namely items number 4, 5, and 6, with each difficulty level of 53.13%, 56.25%, and 46.88%. Two items are included in the difficult category, namely items number 7 and 8 with a difficulty level of 28.13% and 15.63%, respectively. The number of questions that fall into the category of very easy, easy, medium, and high difficulty levels are presented in the following pie chart.
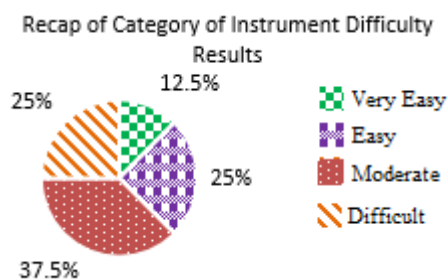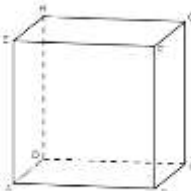

Figure 10.
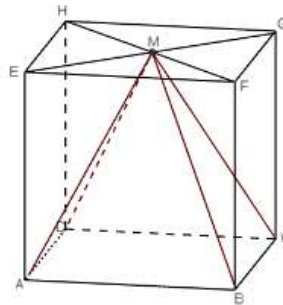
Category of Instrument Difficulty Results

The final result of the geometry van Hiele's Theory test used following Table 4:

Tabel 4.

Student's Spatial Reasoning Ability Test Items

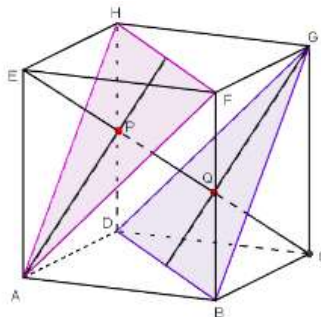| No	Level Van Hiele	Items
1	Level 0 (Visualisasi)	Consider the following picture ABCD.EFGH cube! From the figure above, draw: a) The distance from point A to point G! b) The distance from point B to the AF line! c) The distance from the intersection point of the diagonal ABCD to the point where the diagonal BCGF intersects! d) Distance from point C to the BDG plane! e) If there is a point P which is the intersection of the diagonals of sides AC and BD, and a point Q which is the point of intersection of the diagonals of sides EG and FH, draw a line segment that represents the distance between lines PE and CQ! f) Distance from line AB to DCFE plane! g) The distance between the BDE plane and the CFH plane!

2	Level 1 (Analysis)	Hesti made a box in the form of a block with a size of 5×4×3 cm. Ani and Mila also made blocks in the shape of blocks. The block made by Ani has a size of 3×4×5 cm, while the block made by Mila has a size of 5×3×4 cm. Does each of the blocks made by Ani and Mila have the same space and side diagonals as Hesti's blocks?
3	Level 2 (Abstraction)	Consider the following picture! Construct the space cube ABCD.EFGH above has a side length of 8 cm. The point M is the point of intersection of the diagonals of the sides EG and FH. If point M is connected to points A, B, C, and D, a rectangular pyramid will be formed. If there is a point N that is in the middle of line AB, determine the distance of point N to line BM!
4	Level 3 (Formal Deduction)	Consider the following picture! The cube ABCD.EFGH above has side length a cm. There are two planes, namely the AFH and BDG planes in the cube. The line CE is the diagonal of the cube space. Are the line segments CQ, QP, and PE the same length?

Spatial Reasoning Ability Results

The trial use of the test that has been developed to measure spatial reasoning ability was given to 28 students of class XII IPA 3 MAN 1 Kuningan. The instrument given has been in final form with a total of 4 items and each item represents the Van Hiele level from level 0 to level 3. The instrument questions taken are items that have significant item correlations and good distinguishinging power.

The students' spatial reasoning ability is categorized into three levels. The range of scores is obtained by referring to the Norm Reference Assessment (NRA) with three categories. After getting the results of the spatial reasoning ability score category using the standard deviation and the average overall score of students in one class, the researchers then calculated the total final score obtained by the students and classified the students, whether they were included in the high, medium or low category. The results of the calculation of the scores obtained by students are categorized as follows.
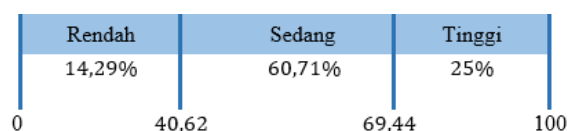

Figure 11.
Spatial Reasoning Ability Results

CONCLUSION

The quality of the Van Hiele geometry test, which was developed to measure the level of students' spatial reasoning abilities, was declared valid and reliable with a reliability of 0.89. This means that the test developed is in accordance with what is intended to be measured and has constant consistency. The estimation of distinguishing power and the level of difficulty of the test were analyzed using Anates V.4.0.5 software. The results of the estimation of the distinguishing power of the questions as a whole were stated to be quite good, while the level of difficulty of the test obtained 1 question with very easy interpretation, two questions with easy interpretation, three questions with moderate interpretation, and two questions with difficult interpretation. The level of spatial reasoning ability of class XII IPA MAN 1 Kuningan students based on the tests that have been developed is mostly in the medium category with a percentage of 60.71%. 14.29% of students who have high spatial reasoning ability and 25% have low spatial reasoning ability.

BIBLIOGRAPHY

Abdussakir, A. (2009). Pembelajaran Geometri sesuai Teori Van Hiele. *Madrasah: Jurnal Pendidikan dan Pembelajaran Dasar*, *2*(1). https://doi.org/10.18860/jt.v2i1.1832

Afriyanti, I., Wardono, W., & Kartono, K. (2018). Pengembangan Literasi Matematika Mengacu PISA Melalui Pembelajaran Abad Ke-21 Berbasis Teknologi. *PRISMA, Prosiding Seminar Nasional Matematika*, *1*, 608-617. Retrieved from https://journal.unnes.ac.id/sju/index.php/prisma/article/view/20202

Aliman, M., Ulfi, T., Lukman, S., & Muhammad, H. H. (2019). Konstruksi Tes Kemampuan Berpikir Spasial Model Sharpe-Huynh. *Jurnal Georafflesia*. Retrieved from https://journals.unihaz.ac.id/index.php/georafflesia

Ana, B. S. aacute nchez G. iacute a, & Ana, B. eacute n C. (2016). An instrument for measuring performance in geometry based on the van Hiele model. Educational Research and Reviews, 11(13), 1194–1201. https://doi.org/10.5897/err2016.2801

Astuti, R. N. Kemampuan Penelaran Spasial Matematis Siswa dalam Geometri di Sekolah Menengah Pertama. *Jurnal Pendidikan dan Pembelajaran Khatulistiwa*, *5*(10). Retrived from https://jurnal.untan.ac.id/index.php/jpdpb/article/view/17211

Azwar, S. (2015). *Dasar-Dasar Psikometri (2nd ed.).* Yogyakarta: Pustaka Pelajar.

Haqq, A. A. (2020). Pengembangan Desain Didaktis Geometri Berbantuan Perangkat Lunak Cabri3d pada Pembelajaran Matematika SMA. Jurnal THEOREMS (The Original Research of Mathematics), 5(1), https://doi.org/10.31949/th.v5i1.2215

Haqq, A. A., Nasihah, D., & Muchyidin, A. (2018). Desain Didaktis Materi Lingkaran Pada Madrasah Tsanawiyah. *Eduma: Mathematics Education Learning and Teaching*, *7*(1), 71-82. https://doi.org/10.24235/eduma.v7i1.2731

Haqq, A. A., & Toheri, T. (2019). Reduksi Hambatan Belajar melalui Desain Didaktis Konsep Transformasi Geometri. *SJME (Supremum Journal of Mathematics Education)*, *3*(2), 117-127. https://doi.org/10.35706/sjme.v3i2.1901

Muchsin, S. B., Kamaruddin, R., & Rosida, V. (2018, June). Developing Learning Instruments of Geometry Based on Van Hiele Theory to Improving Students' Character. In *Journal of Physics: Conference Series* (Vol. 1028, No. 1, p. 012137). IOP Publishing. https://doi.org/10.1088/1742-6596/1028/1/012137

Razak, F., & Sutrisno, A. B. (2017). Analisis Tingkat Berpikir Siswa Berdasarkan Teori Van Hiele pada Materi dimensi tiga ditinjau dari gaya kognitif field dependent. *Edumatica: Jurnal Pendidikan Matematika*, *7*(02), 22-29. https://doi.org/10.22437/edumatica.v7i02.4214

Rikanah, D., & Winarso, W. (2016). Penguasaan Konsep Lingkaran Terhadap Kemampuan Spasial Matematika Siswa Pokok Bahasan Bangun Ruang Sisi Lengkung Kelas VIII SMP Negeri 1 Kota Cirebon. *Jurnal Pendidikan Matematika Sriwijaya*, *10*(1), 15-25. https://doi.org/10.22342/jpm.10.1.3266.15-25

Risma, D. A., Putri, R. I. I., & Hartono, Y. (2013). On Developing Students' Spatial Visualisation Ability. *International Education Studies*, *6*(9), 1-12. https://doi.org/10.5539/ies.v6n9p1

Ristontowi. (2013). Kemampuan Spasial Siswa Melalui Pendekatan Pendidikan Matematika Realiastik Indonesia Dengan Media Geogebra. Seminar Nasional Matematika.

Sakinah, E., Darwan, D., & Haqq, A. A. (2019). Desain Didaktis Materi Trigonometri dalam Upaya Meminimalisir Hambatan Belajar Siswa. *Suska Journal of Mathematics Education*, *5*(2), 121-130. https://doi.org/10.24014/sjme.v5i2.7421

Tajik, N., & Maqsood, M. (2019). Integrating ICT in Mathematics: Evaluating Students' Achievement Using Geogebra Through Van Hiele Model. Iceri2019 Proceedings, 1. https://doi.org/10.21125/iceri.2019.2635

Tian, Z., & Huang, X. (2009). A study of children's spatial reasoning and quantitative reasoning abilities. *Journals of Mathematic Education*, *2*(2), 80-93.

Williams, C. B., Gero, J., Lee, Y., & Paretti, M. (2010, January). Exploring spatial reasoning ability and design cognition in undergraduate engineering students. In *International Design Engineering Technical Conferences and Computers and Information in Engineering Conference* (Vol. 44144, pp. 669-676). https://doi.org/10.1115/DETC2010-28925