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STUDENT'S VISUAL REASONING IN SOLVING LINEAR EQUATIONS IN TERMS OF LEARNING STYLE

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Abstract

This study aims to describe students' visual mathematical reasoning abilities based on visual learning styles, auditory, and kinesthetic (VAK) in solving systems of linear equations. The research approach used is qualitative with a case study design. The research subjects involved were 30 students of class VIII at a private school in Surakarta. The research instrument used was a VAK learning style questionnaire, visual reasoning test (TPV) questions, and interview guidelines. Data analysis was carried out inductively, namely data collection, data reduction, data presentation, and drawing conclusions. The results showed that there was a diversity of students' reasoning abilities based on learning styles. Although visual and auditory students are able to present mathematical expressions in visual form in the form of graphs, their ability to describe graphs is relatively diverse. In other words, visual and auditory students have various abilities on various investigative indicators. Meanwhile, students with kinesthetic learning styles cannot present mathematical expressions in the form of graphs so they cannot describe visual objects. In other words, kinesthetic students are not able to fulfill the investigation indicators. Thus, it can be concluded that the visual reasoning ability of the kinesthetic student's investigative dimension is the weakest compared to the visual and auditory learning styles. Meanwhile, the dimensions of student investigation with visual and auditory learning styles are relatively diverse.

Keywords: visual reasoning, learning style, linier equations

Abstrak

Penelitian ini bertujuan mendeskripsikan kemampuan penalaran visual matematis siswa berdasarkan gaya belajar visual, auditori, dan kinestetik (VAK) dalam menyelesaikan sistem persamaan linier. Pendekatan penelitian yang digunakan kualitatif dengan desain studi kasus. Subjek penelitian yang terlibat sebanyak 30 siswa kelas VIII pada salah satu sekolah swasta di Surakarta. Instrumen penelitian yang digunakan yaitu angket gaya belajar VAK, soal tes penalaran visual (TPV), dan pedoman wawancara. Analisis data dilakukan secara induktif yaitu pengumpulan data, reduksi data, penyajian data, dan penarikan kesimpulan. Hasil penelitian menunjukkan terdapat keragaman kemampuan penalaran siswa berdasarkan gaya belajar. Meskipun siswa visual dan auditori mampu menyajikan ekspresi matematika dalam bentuk visual berupa grafik, namun kemampuan mendeskripsikan grafik relatif beragam. Dengan kata lain, siswa visual dan auditori mempunyai kemampuan beragam pada indikator investigasi beragam. Sedangkan siswa dengan gaya belajar kinestetik tidak dapat menyajikan ekspresi matematika dalam bentuk grafik sehingga tidak dapat melakukan deskripsi terhadap objek visual. Dengan kata lain, siswa kinestetik tidak mampu memenuhi indikator investigasi. Dengan demikian dapat disimpulkan kemampuan penalaran visual dimensi investigasi siswa kinestetik paling lemah dibandingkan gaya belajar visual dan auditori. Sementara, dimensi investigasi siwa dengan gaya belajar visual dan auditori relatif beragam.

Kata kunci: penalaran visual, gaya belajar, persamaan linier

INTRODUCTION

Reasoning ability affects students' ability to solve problems of everyday life (OECD, 2015). Reasoning ability is also one of the standards of the mathematics learning process, in addition to other abilities such as problem solving, communication, connection skills, and representation (NCTM, 2000). Reasoning ability is the ability of students to understand and

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predict the need or adequacy of data on mathematical problems to be able to draw conclusions (Saleh et al., 2018).

Reasoning ability is considered to play an important role in various types of cognitive activity. Activation of metacognitive skills can create students' self that can affect the improvement of higher order thinking skills (reasoning skills) (Setiawan & Supiandi, 2019). Visual reasoning is one of the reasoning abilities related to understanding visual information in the form of geometric or graphic representations that represent the relationship between mathematical expressions, building relationships between visual information, and the ability to express visual information as mathematical relationships (Gülşen, 2012). From the various experiences experienced by students and teachers, one of them has difficulty in combining problem solving and reasoning in mathematics subjects (Sullivan et al., 2015). In learning mathematics requires many types of mathematical reasoning that students use to interpret everyday life (Öztürk et al., 2021). Reasoning really helps students in generating knowledge to solve problems through evidence-based reasoning (Tajudin & Chinnappan, 2015).

Visualization is the ability, process and product of creating, interpreting, using and reflecting on images, diagrams, in our minds, on paper or with technological tools, with the aim of describing and communicating information, thinking and developing previously unknown ideas and more advanced understanding (Natsheh & Karsenty, 2014). Visual reasoning has proven to be a vital ability to understand the behavior of functions and interpret related inherited properties (Hamid, 2017). Visualization is related to External Representation, a systematic and focused public display of information in the form of images, diagrams, tables, and the like (Ozge, 2015).

There are three indicators of visual reasoning, namely investigation, interpretation, and application(Abd Hamid & Idris, 2014). Investigation is reading pictures/graphs by reading information directly as shown in pictures/graphs. Interpretation is reading between pictures/graphs with pictures/graphs and making connections between the information displayed in pictures/graphs. While the application is reading outside of pictures/graphs by making deductions and conclusions from the information displayed in pictures/graphs (Abd Hamid & Idris, 2014). Visual reasoning has an important role as a complement to verbal reasoning where visual and spatial reasoning includes mental skills related to visual understanding, manipulating, rearranging, or interpreting relationships so as to facilitate mathematical understanding (Geçici & Türnüklü, 2021).

The importance of learning styles for students because it can help teachers and other educators in the development of teaching and will result in academic improvement of students in schools. Learning styles to assist an educator in designing, implementing, and evaluating instructions for all subjects, especially mathematics(Banas, 2018). Learning styles play an important role in learning where students can easily receive information or material through the learning method used (Ha, 2021). The learning styles of adult learners do not have a single fixed learning style, but they do have a dominant learning style depending on the situation and context. One effort to justify the use of learning styles is to improve student learning through individualization (Amponsah, 2020). Learning styles play an important role in achieving learning goals, namely as a powerful tool for schools, teachers, and lecturers(Alonso-Martín et al., 2021).

Learning style is a way in which a student can process and search for information. Learning style is very important in the learning process because it can improve the quality of education and help individual learning(Hamdani, 2015). VAK identifies three types of learners based on how learners learn more effectively namely first, visual learners are those who learn best things through seeing them, second, auditory learners are those who learn best things through hearing them and third, kinesthetic/tactile learners. They do best when physically involved with the environment, such as by playing games or conducting demonstrations (Sousa, 2006). Learning style is one way of learning that each individual has in the learning process, namely selecting, receiving, absorbing, storing, processing, and processing information (Ridwan, 2017). Learning styles are methods in learning that are used to make it easier for students to understand explanations in learning(Zulfah et al., 2021). Stating learning styles as an important element that must be considered in the teaching and learning process to realize the expected learning objectives (Putri et al., 2022).

SPLDV material is one of the mathematical topics presented in the form of stories so that it is related to contextual problems (Mendikbud, 2020). In solving the SPLDV problem, there are still students who have difficulty understanding the problem so that it is difficult to apply the SPLDV concept to solve the problem (Rahmawati et al., 2019). In addition, students in solving SPLDV problems also have difficulty using symbols and applying the concepts of elimination and substitution (Puspitasari et al., 2015). As previously explained, students' success in solving math problems is influenced by their reasoning abilities and learning styles. Therefore, research that links students' reasoning abilities, especially visual reasoning, with differences in student learning styles is very important to study.

This study aims to explore students' visual reasoning abilities in solving linear equation problems in terms of students' learning styles. In this study, researchers focused on visual, auditory, and kinesthetic learning styles. Understanding of student learning styles can assist teachers in designing learning that is in accordance with the characteristics of students' learning styles.

METHODS

This research uses a qualitative approach with a case study design. The subjects involved in this study were 30 grade VIII students at a private school in Surakarta. The instruments used in this study included questions on the visual reasoning test (TPV) by adopting SPLDV material questions from the revised 2013 curriculum VIII grade textbook published by the Ministry of Education and Culture, questionnaires VAK (Visual-Auditory-Kinesthetic) learning style which refers to Bobbi DePorter et al. (2010), and interview guidelines. Before being used for research, all instruments were validated by two mathematicians. Based on the validation results, two TPV questions were obtained as presented in Table 1.

Table 1. The Question of Visual Reasoning Ability

No	Soal
1.	It is known that the system of equations x + y = 3 and xy = 3, using the graphical method determine the values of x and y ?
2.	Rani bought 4 notebooks and 3 pencils for Rp12.000,00. Budi bought 2 notebooks and 4 pencils for Rp16,000.00. If Farida was going to buy 5 notebooks and a pencil, how much money would she have to pay?(use the graphical method)

In this study, the researcher only focused on investigation indicators on visual reasoning according to the characteristics of the questions presented. To assign a score to the TPV, the researcher used the scoring rubric as presented in Table 2.

Table 2. TPV Assessment Rubric for Investigation aspects

Skor	Keterangan
0	Students are not able to read and understand visual images
1	Students are able to read and understand visual images but are not precise
2	Students are able to read and understand visual images correctly

Next, the researcher gave a learning style questionnaire to 30 students to identify the dominant learning style preferences in each student. The results of the learning style questionnaire of 30 students based on the VAK model are presented in Table 3.

Table 3. Grouping Type of Learning Style

No	Type of learning style	Number of students
1	Visual	8
2	Audio	8
3	Kinesthetic	14

Based on the data in Table 3 the researchers chose for each learning style, two students who had a high TPV score were interviewed. Researchers used a semi-structured interview model to make it easier for researchers to dig deeper information related to the students' investigation process in solving TPV questions. The data validation in this study used triangulation of sources3 and techniques. In source triangulation, the researcher uses two subjects in each learning style which aims to find the consistency of the reasoning process on subjects with the same learning style. Then, in the triangulation technique, the researcher used two kinds of data collection instruments to reveal the visual reasoning ability of the investigative aspect, namely TPV questions and interview guidelines. Furthermore, the data analysis process is carried out inductively, namely the researcher begins by collecting data, then reducing the data, presenting the data with a purpose, verification, and finally drawing conclusions.

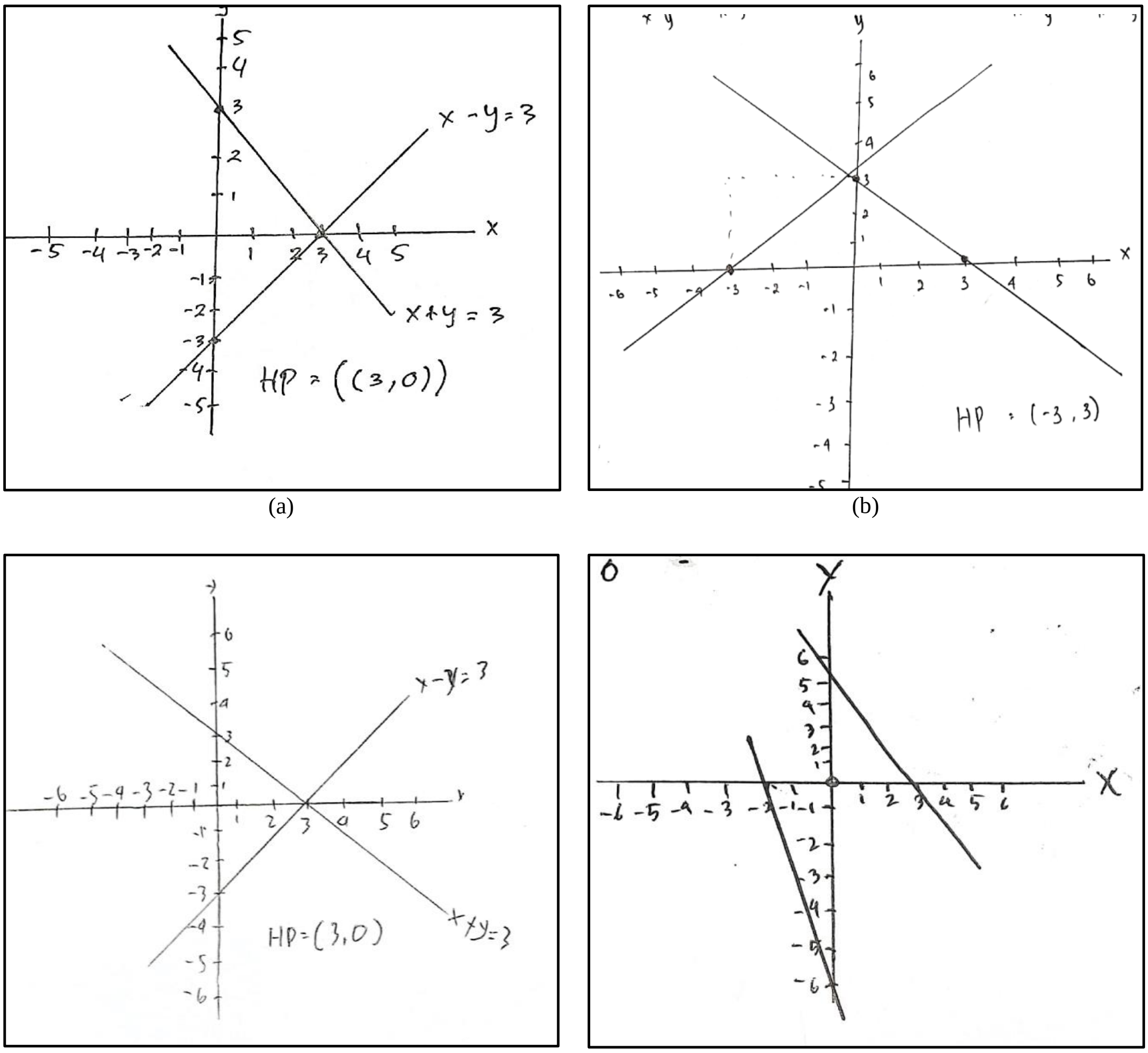
RESULTS AND DISCUSSION

Result

Analysis of Question Number 1

Figure 1.(a)-(d) is the answer of visual and auditory subjects in solving problem number 1. Figure 1 (a) shows that V_1, a visual subject with high ability, can create system graphics linear equation $x + y = 3$ and $x - y = 3$ exactly. V_1 firstly finds the point of intersection of

each equation on the -*x* and *y*. Substituting $x = 0$ in both equations, we get the intersection point of equation $x + y = 3$ with respect to $-x$is $(0,3)$ and the intersection point of equation $x - y = 3$ with respect to -*x* $is(0, -3)$. Likewise, by substituting $y = 0$ in both equations, we get the intersection point of the equation $x + y = 3$ with respect to -*y* namely $(3,0)$ and the intersection point of the equation $x - y = 3$ with respect to $-y$ which is $(3,0)$. Then V_1 makes the graphic of the two equations based on the intersection point obtained and determines the solution set. It appears that V_1 can graph and determine the solution set for a system of linear equations using graphs correctly.



(a) (b) (c) (d)

Figure 1. Answers to Question Number 1 of Subjects: V_1 (a), V_2 (b), A_1 (c), and A_2 (d)

Next researcher (P) conducted an interview with V_1regarding the completion of question number 1.

P : Can you explain the steps for solving problem number 1?

V_1 : My first step is to find the point of intersection of the two equations, namely the equation $x + y = 3$ and $x - y = 3$. In equation 1. i.e. $x + y = 3$ if I substitute the value of $x = 0$ into equation 1, we get the value of $y = 3$ so we get the point (0.3). If I enter the value of $y = 0$ then the value of $x = 3$ so that the point $(3,0)$. In equation 2, which is $x - y = 3$ for the same steps as equation 1, the method is that if I substitute the value of $x = 0$ into equation 1, the value of $y = -3$. So the point $(0, -3)$. If I substitute the value of $y = 0$ then we get the value of $x = 3$ so that the point $(3,0)$.coordinates so that the intersection point $(3,0)$ where $x = 3$ and $\mathrm{y} = 0$

Based on student answers and interview results, it can be concluded that V_1 has been able to accurately describe visual images as indicated by the ability to determine the solution set for a system of linear equations based on the point of intersection of the two equations on the graph. In other words, V_1 is able to meet the investigation indicators.

In Figure 1 (b), V_2, a visual subject with low ability, can graph a system of linear equations $x + y = 3$ and $x - y = 3$ but it is not accurate. V_2 looks for a solution to the system of linear equations as did $V_1$is to determine the intersection point of each equation on the x and y, followed by drawing a graph. V_2 can determine the intersection point of the equation $x + y = 3$ with the x and y correctly. However, V_2 has an error in determining the intersection point of the equation $x - y = 3$ with the -x and *y*. In Figure 1 (b) it can be seen that V_2 has substituted the values of $x = 0$ and $y = 0$ in the equation $x - y = 3$. However, V_2 is less precise in presenting the intersection points obtained. Supposedly the point of intersection of the equation $x - y = 3$ with the -x is $(0, -3)$ and the y-axis is $(3,0)$. However, V_2 writes the intersection point of the equation with the $x$axis $(-3,0)$ and with the -y is $(0,3)$. However,V_2 writes the intersection point of the equation with the x is $(-3,0)$ and with the$y$ is $(0,3)$. Furthermore, V_2 experienced an error in determining the solution set for the system of linear equations based on the graph that had been compiled. V_2 writes the solution set with $(-3,3)$. It appears that V_2 has not understood the meaning of solving a system of linear equations.

Furthermore, the researcher conducted an interview with V_2related to number 1 which is presented as follows.

P : Can you explain the steps for solving problem number 1?

V_2 : My first step is to find the point of intersection of the two equations, namely the equation $x + y = 3$ and $x - y = 3$. In the equation $x + y = 3$ I substitute the value of $x = 0$ into the equation so that the value of $y = 3$is obtained. So the point (0.3). Then I enter the value of $y = 0$ then the value of $x = 3$ so that the point $(3,0)$. In the $x - y = 3$ steps are the same as before, that is, if I substitute the $x = 0$ into the equation, the $y = -3$ is obtained, so we get a point $(0, -3)$. Then if I substitute the value of $y = 0$ then we get the value of $x = 3$ so that the point $(3,0)$.coordinates x and y so the graph is wrong. It should intersect with the x is (0,-3) and with the -yis (3,0).

Based on the results of the interview, V_2 understands the steps of graphing and realizes the mistakes made in presenting the intersection point of the equation $x - y = 3$. However, V_2 is not aware of the error in determining the solution set of the system of equations based on the graph obtained. This shows that V_2 has not been able to describe the graphic image properly. In other words, V_2 has not been fully able to meet the investigation indicators.

In Figure 1 (c), A_1, an auditory subject with high ability, can graph the system of linear equations $x + y = 3$ and $x - y = 3$ correctly. As with the steps for solving the subject V_1, A_1 first determines the intersection point of each equation on the x and y, followed by drawing a graph. A_1 is able to determine solution set of a system of equations using graphs correctly. The results of the researcher's interview with A_2 show that $A_1$is able to understand the steps of making graphs and is able to describe graphs correctly.

P : Can you explain the steps for solving problem number 1?

A_1 : In equation 1, which is $x + y = 3$ the way is if I substitute the value of $x = 0$ into equation 1 then the value of $y = 3$ is obtained so the point (0.3) and if I enter the value of $y = 0$ then the value of $x = 3$ so the point is (3,0). In equation 2, namely $x - y = 3$, the steps are the same as in equation 1, the method is that if I substitute the value $x = 0$ into equation 1, the value of $y = -3$ is obtained, so I get a point $(0, -3)$ and if I substitute the value of $y = 0$then the value of $x = 3$so that the point (3,0). after I find the coordinates of the two equations intersection, then I draw the graph in cartesian coordinates so that the intersection point is obtained (3,0) where $x = 3$ and $y = 0$

Based on student answers and interview results, it can be concluded that A_1 has been able to accurately describe visual images as indicated by the ability to determine the solution set for a system of linear equations based on the point of intersection of the two equations on the graph. In other words, V_1 is able to meet the investigation indicators.

In Figure 1 (d), A_2, an auditory subject with low ability, it seems difficult to graph the system of linear equations $x + y = 3$ and $x - y = 3$. A_2 cannot determine the point of intersection of each equation on the -*x* and *y* precisely. As a result, the graph made by A_2 is also not correct. The results of the researcher's interview with A_2 showed that A_2 did not understand the steps of making graphs correctly.

P : Can you explain the steps for solving problem number 1?

A_2 : I have difficulty determining the point of intersection so that the intersection point of the equations $x + y = 3$ and $x - y = 3$ can't be found and in the end I write anywhere equation 1, namely $x + y = 3$ the intersection is at $(0,0)$ and $(3,6)$ while $x - y = 3$ is at the points $(2,0)$ and $(0,6)$. The next step I also have difficulty in drawing graphs so that I draw graphs arbitrarily.

Based on student answers and interview results, it can be concluded that $A_2$is unable to make graphic images properly. Thus, A_2 is also not able to describe the visual image properly. In other words, A_2 is not able to meet the investigation indicators.

Furthermore, on subjects with kinesthetic learning styles $K_{1,}$ and $K_{2,}$students did not make a graph of the solution of the system of equations. Both subjects had difficulty in determining the intersection point and drawing the intersection point on the x and y so that they could not draw a graph. This is supported by the results of interviews with K_1 as follows:

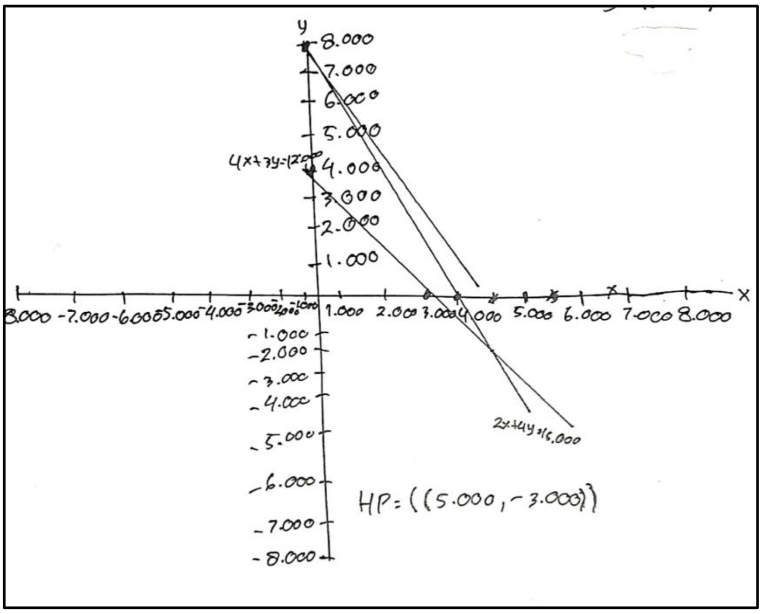
P : Can you explain the steps for solving problem number 1?

K_1 : Problem number 1, I have to draw a graph of a known equation. The first step is to find the point of intersection of the two equations. But I have difficulty determining the point of intersection so I don't understand how to draw the graph

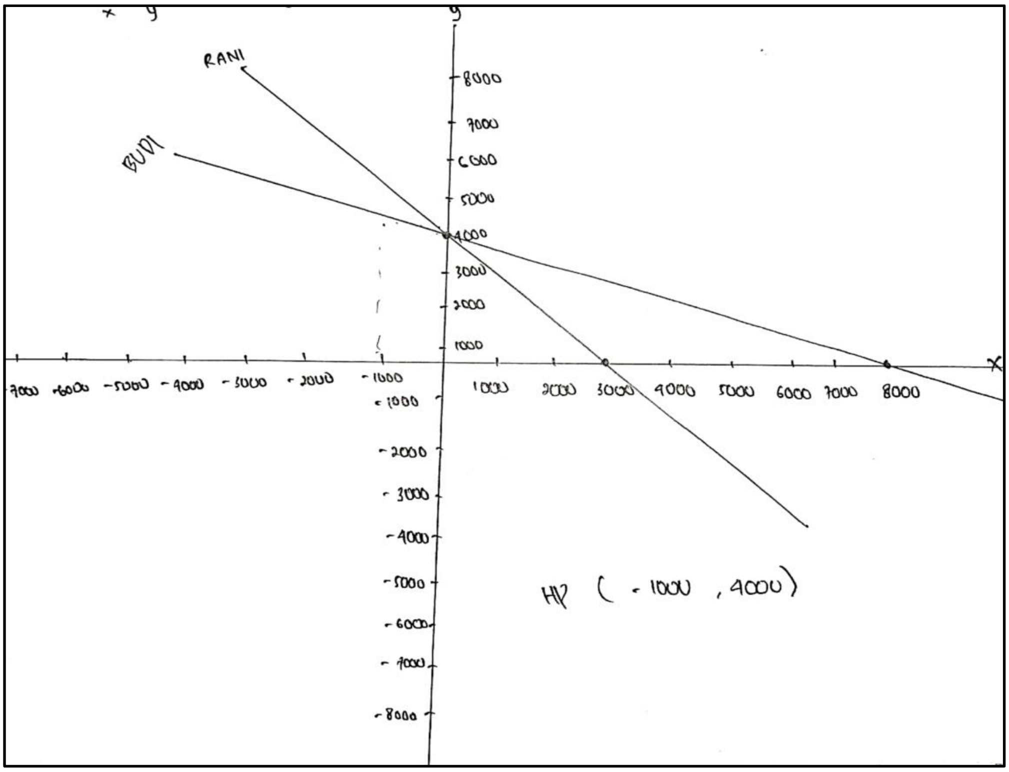
Based on the results of the interview, K_1 difficulty in determining the intersection point of the equation with the x and y. This makes the subject unable to draw graphics. Thus, it can be concluded that K_1not been able to understand graphing so that it results in not being able to read or describe graphs. In other words, the kinesthetic subject has not been able to meet the investigation indicators.

Analysis of Question Number 2

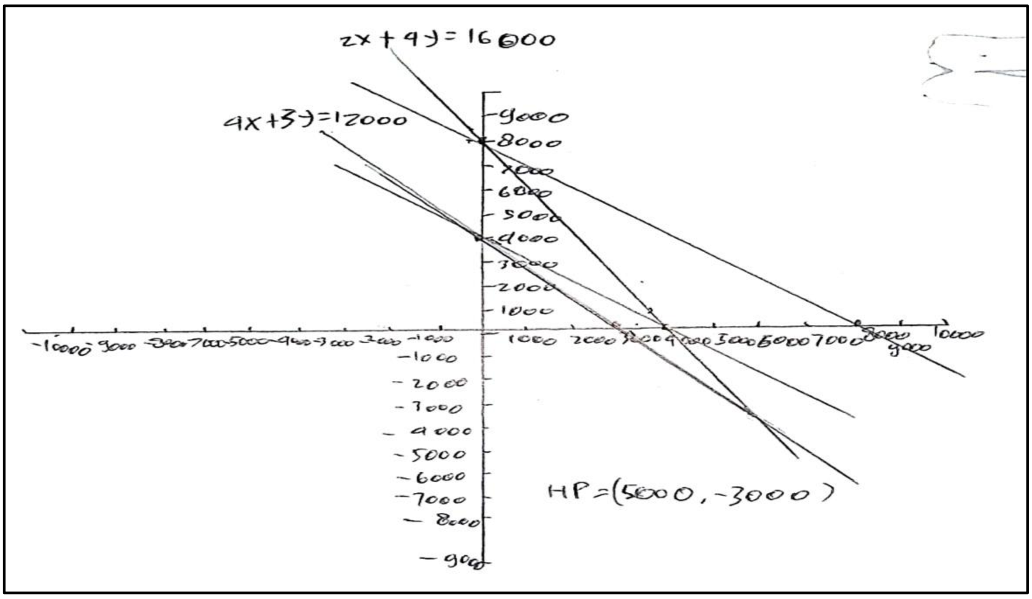
Figure 2 (a) - (c) shows the completion of visual and auditory subjects in solving problem number 2.



(a)



(b)



(c)

Figure 2. Answers to Question Number 2 of Subjects: V_1 (a), V_2 (b) , and A_2 (c)

Figure 2 (a) shows that V_1 can graph the system of linear equations $4x + 3y = 12000$ and $2x + 4y = 16000$ correctly. V_1 finds the point of intersection of each equation on the x and y. Substituting $x = 0$ in both equations, the intersection point of the equation $4x + 3y = 12000$ to x is (0, 4000) and the intersection point of the equation $2x + 4y = 16000$ to the -*x* is (0, 8000). Likewise, by substituting $y = 0$ in both equations, the intersection point of the equation $4x + 3y = 12000$ to the *y* is (3000, 0) and the intersection point of the equation $2x + 4y = 16000$ to the -y is (4000,0). Then V_1 makes the graph of the two equations based on the intersection point obtained and determines the solution set. It appears that V_1 is able to make a graph and determine the set of solutions to a system of linear equations using graphs correctly.

The results of the researcher's interview (P) with V_1that the subject understands the steps of graphing and can make conclusions based on the graphs compiled.

P : Can you explain the steps for solving problem number 2?

V_1 : In equation 1, which is $4x + 3y = 12000$, the method is that if I substitute the value of $x = 0$ into equation 1, we get the value of $y = 4000$ so we get a point (0.4000) and if I enter the value of $y = 0$ then we get the value of $x = 3000$ so the point is $(3000,0)$. In equation 2, which is $2x + 4y = 16000$, the steps are the same as in equation 1, the method is if I substitute the value $x = 0$ into equation 2, the value of $y = 8000$ is obtained so the point is (0.8000) and if I substitute the value of $y = 0$ then the value of $x = 4000$ so that the point

is $(4000,0)$. After I found the coordinates of the two equations, then I drew the graph in Cartesian coordinates.

Based on student answers and interview results, it can be concluded that V_1has been able to accurately describe visual images as indicated by the ability to determine the solution set for a system of linear equations based on the point of intersection of the two equations on the graph. In other words, V_1 is able to meet the investigation indicators.

In Figure 2 (b) it is possible to graph a system of linear equations $4x + 3y = 12000$ and $2x + 4y = 16000$ but not quite right. V_2 looks for a solution to the system of linear equations as did $V_1$is to determine the intersection point of each equation on the -*x* and *y*, followed by drawing a graph. V_2 can determine the intersection point of the equation $4x + 3y = 12000$ with the x and y exactly. However, V_2 has encountered an error in determining the intersection point of the equation $2x + 4y = 16000$ and the equation of $2x + 4y = 16000$ with the -*x* and *y*.

In Figure 2 (b) it can be seen that V_2 has substituted the values of $x = 0$ and $y = 0$ in the equation of $2x + 4y = 16000.$ However, V_2 is less precise in presenting the intersection points obtained. Supposedly the intersection point of the equation $2x + 4y = 16000$ with the x is $(0, 8000)$ and the y is $(4000, 0)$. However, V_2 writes the intersection point of the equation with the x (0, 4000) and with the $y(8000, 0)$. It also appears that V_2 has substituted the values of $x = 0$ and $y = 0$ in the equation $2x + 4y = 16000$. However, V_2 is less precise in presenting the intersection points obtained. Supposedly the intersection point of the equation $2x + 4y = 16000$ with the x is $(0, 3000)$ and the y is $(4000, 0)$. However, V_2 writes the intersection point of the equation with the $x(0, 3000)$ and with the y is $(4000, 0)$. Furthermore, V_2 experienced an error in determining the solution set for the system of linear equations based on the graph that had been compiled. V_2 writes the solution set with $(-1000, 4000)$. It appears that V_2 has not understood the meaning of solving a system of linear equations.

The results of the researcher's interview with V_2 related to the problem of number 2 are presented as follows.

P : Can you explain the steps for solving problem number 2?

V_2 : My first step is to find the point of intersection of the two equations, namely the equations $4x + 3y = 12000$ and $2x + 4y = 16000$. In equation $2x + 4y = 16000$ I substitute the value of $x = 0$ into the equation so that the value of $y = 4000$ is obtained. So I get the point (0.4000). Then I enter the value of $y = 0$ then I get the value of $x = 8000$ so that the point $(8000,0)$. In the equation $4x + 3y = 12000$, the steps are the same as before, that is, if I substitute the value $x = 0$ into the equation, the value of $y = 40000$ is obtained, so the point (0.4000). Then if I substitute the value of $y = 0$ then the value of$x = 3\,000$ the point is $(3000,0)$. Here I am wrong in drawing the point of intersection of the axis coordinates x and y so the graph is wrong. It should be the point of intersection of the two equations with the -x axis (0.3000); (0.8000) and with the -y axis (4000,0) and (4000,0).

Based on the results of the interview, V_2understands the steps of graphing and realizes the mistakes made in presenting the intersection point of the two equations. However, V_2 is not aware of the error in determining the solution set of the system of equations based on the graph obtained. This shows that V_2 has not been able to describe the graphic image properly. In other words, V_2 has not been fully able to meet the investigation indicators.

In Figure 2 (c), A_1can graph the system of linear equations $4x + 3y = 12000$ and$2x + 4y = 16000$ correctly. As with the step of solving subject V_1, A_1 first determines the intersection point of each equation on the -*x* and *y*, followed by drawing a graph. A_1 is also able to determine the solution set to the system of equations using graphs correctly. The results of the researcher's interview with A_1 showed that A_1 was able to make graphs and describe the graphs correctly.

P : Can you explain the steps for solving problem number 2?

A_1 : In equation 1, which is $4x + 3y = 12000$, the method is if I substitute the value of $x = 0$ into equation 1, the value of $y = 4000$ is obtained, so the point is (0.4000) and if I enter the value of $y = 0$ then the value of $x = 3000$ so the point is $(3000,0)$. In equation 2, which is 22

$x + 4y = 16000$, the steps are the same as in equation 1, the method is if I substitute the value $x = 0$ into equation 2, the value of $y = 8000$ is obtained so the point is (0.8000) and if I substitute the value of $y = 0$ then the value of $x = 4000$ so that the point is $(4000,0)$. After I found the coordinates of the two equations, then I drew the graph in Cartesian coordinates.

Based on student answers and interview results, it can be concluded that A_1has been able to accurately describe visual images as indicated by the ability to determine the set of solutions for a system of linear equations based on the point of intersection of the two equations on the graph. In other words, A_1 is able to meet the investigation indicators.

Furthermore, on subject A_2, the results of student answers showed that the subject did not make a graph of the solution of the system of equations. The subject has difficulty in determining the point of intersection and drawing the point of intersection on the coordinates of the x and y so that they cannot draw a graph. This is supported by the results of interviews with A_2 follows.

P : Can you explain the steps for solving problem number 2?

A_2 : The problem of number 2, I don't understand the question of number 2 so I don't understand how to determine the intersection point, draw the coordinates of the intersection point on the x and y and draw a graph so I don't draw the graph.

Based on the results of the interview,A_2 had difficulty in determining the intersection point of the equation with the -x and y. This made the subject unable to draw the graphics. Thus, it can be concluded that A_2 has not been able to understand graphing so that it results in being unable to read or describe the graphs. In other words, auditory subjects with low abilities have not been able to meet the investigation indicators.

At K_1 and K_2 two subjects did not graph the solution of the system of equations. Both subjects had difficulty in determining the intersection point and drawing the intersection point on the x and y so they could not draw a graph. This is supported by the results of interviews with K_1 as follows:

P : Can you explain the steps for solving problem number 2?

K_1 : Question number 2, I forgot a little bit about this material. The first step is to find the point of intersection of the two equations. But I have difficulty in determining the point of intersection so I don't understand how to draw the graph

Based on the results of the interview, K_1 had difficulty in determining the point of intersection of the equation with the x and y. This made the subject unable to draw graphics. Thus, it can be concluded that K_1 has not been able to understand graphing so that it results of not being able to read or describe graphs. In other words, the kinesthetic subject has not been able to meet the investigation indicators.

Discussion

Based on the research results, subjects with visual learning styles can represent linear equations in visual form in the form of graphs. However, from the two visual subjects, there are differences in the ability to describe visual images to determine the solution set for a linear equation system that shows the ability to investigate indicators. $V1$ able to describe visual images accurately.other hand, $V2$ has not been able to properly describe the graphic imageThus, there are differences in students' abilities in investigation indicators on visual subjects. On subjects with auditory learning styles, A_1 has been able to accurately describe visual images as indicated by the ability to determine the solution set for a system of linear equations based on the point of intersection of the two equations on the graph.other hand, A_2 is not able to make a graphic image correctly, which results in the subject being unable to describe the visual image correctly. Thus, in the auditory subject there are also differences in students' abilities in investigative indicators. Furthermore, on subjects with kinesthetic learning styles, both subjects had difficulty in determining the intersection point of the equation with the x and y so that the subjects were unable to draw graphs. Thus, the kinesthetic subject has not been able to understand graphing which results in not being able to read or describe the graph in other words, the kinesthetic subject has not been able to meet the investigation indicators.

The visual reasoning ability of each individual has different characteristics. The results showed the diversity of visual reasoning abilities in students with visual, auditory, and kinesthetic learning styles. Subjects with visual and auditory learning styles are able to represent mathematical expressions in the form of linear equations in visual form in the form of graphs. Although the ability of the four subjects to describe the visual images obtained varied. On the other hand, subjects with kinesthetic learning styles are not able to represent the visual form of mathematical expressions in the form of linear equations. As a result, the kinesthetic subject cannot fulfill the investigation indicators, namely reading and understanding visual images.

The results of this study are in line with Ningsih's research which states that students with visual learning styles are good at solving reasoning problems (Bobbi DePorter et al., 2010). Mathematical problem solving ability has an important role in learning mathematics in the 2013 curriculum which makes education must prepare a new generation that has high-order thinking skills in solving a problem(Amalia & Hadi, 2021). Learning style is a combination of how to absorb, organize and process information that affects learning outcomes(Ridwan, 2017). Reasoning ability is an ability that must be possessed and used by students when faced with mathematical problems that should be solved(Nurhayati & Subekti, 2017). Solving math problems must use reasoning. Students' learning styles have a significant influence on mathematical reasoning abilities(Putri et al., 2022). Research conducted by Zulfah et al.(2021)showed that visual subjects only met three indicators of mathematical reasoning, namely, students were able to demonstrate the reasoning process and were able to determine the initial steps and methods correctly, besides that students were less thorough so that there were some incorrect calculations. Auditory and kinesthetic subjects met four indicators of mathematical reasoning. Auditory subjects are able to present complete information about questions, the first step in solving questions is correct and in providing very clear and complete arguments. Meanwhile, the kinesthetic subject did not write down information on the question of proposing conjectures, compiling and giving reasons for the correctness of the answers.

CONCLUSION

There are differences in students' visual reasoning abilities in the investigative dimension in terms of differences in visual, auditory, and kinesthetic learning styles. Students with visual and auditory learning styles are able to present mathematical expressions in the form of linear equations in graphic form. However, there are differences in students' abilities in describing various graphs. There are visual and auditory students who are able to describe graphs correctly. However, there are also visual and auditory students who cannot describe properly. Students with kinesthetic learning styles are not able to present mathematical expressions in visual form, this results in students not being able to meet the investigation indicators. This study provides useful information for educators to better understand the characteristics of students' visual reasoning abilities from various types of learning styles. This can help educators to design learning according to the characteristics of individual student differences, one of which is learning styles. Although the results of this study are valuable, this study has limitations, namely the subjects involved are only two people for each learning style and the material used to measure visual reasoning abilities is only linear equations.

Further research with other topics in mathematics and broadening the subject will provide more complete information regarding the relation of visual reasoning to students' learning styles. In addition to the limitations, the results of the study that show the diversity of visual and auditory students' investigative abilities need to be studied further regarding the factors that cause the emergence of diversity of abilities.

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REFERENCES

Abd Hamid, H., & Idris, N. (2014). Assessing Pre-University Students’ Visual Reasoning: A Graphical Approach. In *International Journal Of Assessment And Evaluation In Education* (Vol. 4, Issue 18).

Alonso-Martín, P., Cruz-Díaz, R., Granado-Alcón, C., Lago-Urbano, R., & Martínez-García, C. (2021). Variability Of Higher Education Students’ Learning Styles Depending On Gender, Course, Degree And Institutional Context. *Sustainability (Switzerland)*, *13*(4), 1–18. Https://Doi.Org/10.3390/Su13041659

Amalia, R. Z., & Hadi, W. (2021). Analisis Kemampuan Pemecahan Masalah Matematis Bermuatan Higher-Order Thinking Skills Ditinjau Dari Gaya Belajar Siswa. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *10*(3), 1564. Https://Doi.Org/10.24127/Ajpm.V10i3.3743

Amponsah, S. (2020). Exploring The Dominant Learning Styles Of Adult Learners In Higher Education. *International Review Of Education*, *66*(4), 531–550. Https://Doi.Org/10.1007/S11159-020-09845-Y

Banas, R. A. (2018). Perceptual Learning Styles Of Students And Its Effect To Their Academic Performance. *International Journal Of Trend In Scientific Research And Development*, *Volume-3*(Issue-1), 401–409. Https://Doi.Org/10.31142/Ijtsrd18992

Bobbi Deporter, Mark Reardon, & Sarah Singer-Nourie. (2010). *Quantum Teaching: Mempraktikan Quantum Learning Di Ruang-Ruang Kelas*.

Geçici, M. E., & Türnüklü, E. (2021). Visual Reasoning In Mathematics Education: A Conceptual

Framework Proposal. *Acta Didactica Napocensia*, *14*(1), 115–126. Https://Doi.Org/10.24193/Adn.14.1.9

Gülşen, İ. (2012). *Matematik Öğretmen Adaylarının Görsel Akıl Yürütme Durumlarının Incelenmesi [Investıgatıon Of The Visual Reasoning Process Of The Pre-Service Mathematics Teachers]*. Gazi University.

Ha, N. T. T. (2021). Effects Of Learning Style On Students Achievement : Experimental Research. *Linguistics And Culture Review*, *5*(S3), 329–339. Https://Doi.Org/Https://Doi.Org/10.21744/Lingcure.V5ns3.1515

Hamdani, D. Al. (2015). Exploring Students' Learning Style At A Gulf University: A Contributing Factor To Effective Instruction. *Procedia - Social And Behavioral Sciences*, *176*, 124–128. Https://Doi.Org/10.1016/J.Sbspro.2015.01.452

Hamid, H. A. (2017). *Visual Reasoning In Solving Mathematical Problems On Functions And Their Derivatives Among Malaysian Pre-University Students*. University Of Malaya.

Mendikbud. (2020). AKM Dan Implikasinya Pada Pembelajaran. *Pusat Asesmen Dan Pembelajaran Badan Penelitian Dan Pengembangan Dan Perbukuan Kementerian Pendidikan Dan Kebudayaan*, 1–37.

Natsheh, I., & Karsenty, R. (2014). Exploring The Potential Role Of Visual Reasoning Tasks Among Inexperienced Solvers. *ZDM - International Journal On Mathematics Education*, *46*(1), 109–122. Https://Doi.Org/10.1007/S11858-013-0551-1

NCTM. (2000). *Principles And Standards For School Mathematics*. National Council Of Teachers Of Mathematics.

Nurhayati, E., & Subekti, F. E. (2017). Deskripsi Kemampuan Penalaran Matematis Siswa Ditinjau Dari Gaya Belajar Dan Gender. *Alphamath: Journal Of Mathematics Education*, *3*(1), 66–78.

OECD, P. (2015). Assessment And Analytical Framework: Science. In *Reading, Mathematic And Financial Literacy,(Interscience: Paris, 2016)*.

Ozge, E. (2015). *New Approaches To Visual Reasoning In Mathematics And Kantian Characterization Of Mathematics*.

Öztürk, M., Demir, Ü., & Akkan, Y. (2021). Investigation Of Proportional Reasoning Problem Solving Processes Of Seventh Grade Students: A Mixed Method Research. *International Journal On Social And Education Sciences*, *3*(1), 48–67.

Https://Doi.Org/10.46328/Ijonses.66

Puspitasari, E., Yusmin, E., & Nursangaji, A. (2015). Analisis Kesulitan Siswa Menyelesaikan Soal Cerita Materi Sistem Persamaan Linear Dua Variabel Di SMP. *Syria Studies*, *7*(1), 37–72.

Putri, D. F. P., Ekawati, R., & Fiangg, S. (2022). Kemampuan Penalaran Matematika Siswa Dalam Pemecahan Masalah Matematika Ditinjau Dari Gaya Belajar Dinda. *Jurnal Pendidikan Matematika Undiksha*, *13*(1), 2599–2600.

Rahmawati, N. S., Bernard, M., & Akbar, P. (2019). Analisis Kemampuan Komunikasi Matematik Siswa Smk Pada Materi Sistem Persamaan Linier Dua Variabel (SPLDV). *Journal On Education*, *1*(2), 344–352. Https://Doi.Org/Https://Doi.Org/10.31004/Joe.V1i2.74

Ridwan, M. (2017). Profil Kemampuan Penalaran Matematis Siswa Ditinjau Dari Gaya Belajar [Profile Of Students' Mathematical Reasoning Ability Viewed From Learning Style]. *Kalamatika Jurnal Pendidikan Matematika*, *2*(2), 193–205.

Saleh, M., Prahmana, R. C. I., Isa, M., & Murni. (2018). Improving The Reasoning Ability Of Elementary School Student Through The Indonesian Realistic Mathematics Education. *Journal On Mathematics Education*, *9*(1), 41–53. Https://Doi.Org/10.22342/Jme.9.1.5049.41-54

Setiawan, B., & Supiandi, M. I. (2019). The Contribution Of Metacognitive Skills And Reasoning Skills On Problem Solving Ability Based On Problem Based Learning (PBL) Model. *Anatolian Journal Of Education*, *3*(2), 75–86. Https://Doi.Org/10.29333/Aje.2018.327a

Sousa, D. A. (2006). How The Brain Learn. In *T And D* (Vol. 64, Issue 5).

Sullivan, P., Walker, N., Borcek, C., & Rennie, M. (2015). Exploring A Structure For Mathematics Lessons That Foster Problem Solving And Reasoning. *Mathematics Education In The Margins*, 41–56.

Tajudin, N. M., & Chinnappan, M. (2015). Exploring Relationship Between Scientific Reasoning Skills And Mathematics Problem Solving. *Mathematics Education In The Margins (Proceeding Of The 38th Annual Conference Of The Mathematics Education Research Group Of Australasia)*, 603–610. Https://Eric.Ed.Gov/?Id=ED572516

Zulfah, N. A. A., Kusumaningsih, W., & Endahwuri, D. (2021). Profil Kemampuan Penalaran Matematis Dalam Menyelesaikan Soal Cerita Ditinjau Dari Gaya Belajar Siswa. *Jipmat*, *6*(2), 277–284. Https://Doi.Org/10.26877/Jipmat.V6i2.9495