24 (1), 2023, 84-97
Jurnal Pendidikan MIPA
e-ISSN: 2685-5488 | p-ISSN: 1411-2531
http://jurnal.fkip.unila.ac.id/index.php/jpmipa/

Direct Current Electric Circuit-Visualization Skills Instrument Test (DCEC-ViSIT) to Measure High School Student's Visualization Skills

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Abstract: This research aims to develop instrument test visualization skills on direct current electric circuits. The research method used is the development of a 4D model consisting of defining, designing, developing, and disseminating. The participants in this research consisted of 33 high school students in West Java who were randomly selected. The first analysis is an analysis of the results of expert validation using CVR, which is considered valid. The second analysis is the Rasch analysis, which obtained raw variance data with special interpretation and declared the questions valid. The third stage is the analysis of the parameters of the items included in the interpretation of "very appropriate" and "appropriate". The fourth stage of the reliability analysis used Rasch analysis, which showed that overall visualization skills items were reliable with a Cronbach Alpha of 0.71. But the consistency of the answers from the respondents is weak. Students' visualization skills need to be improved through models, methods, and visual media that support visualization skills.

Keywords: visualization skills, direct current electrical circuits, 4D model, Rasch analysis.

Abstrak: *Penelitian ini bertujuan untuk mengembangkan instrument test visualization skills pada rangkaian listrik arus searah. Metode penelitian yang digunakan yakni pengembangan model 4D yang terdiri dari defining, designing, developing, dan disseminating. Partisipan dalam penelitian ini terdiri dari 33 siswa SMA di salah satu SMA Negeri di Jawa Barat yang dipilih secara acak. Analisis pertama adalah analisis hasil validasi ahli menggunakan CVR yang termasuk valid. Analisis kedua adalah analisis Rasch didapatkan raw varian data dengan interpretasi istimewa dan soal dinyatakan valid. Tahap Ketiga adalah analisis parameter butir soal termasuk dalam interpretasi "sangat sesuai" dan "sesuai". Tahap keempat analisis reliabilitas menggunakan analisis Rasch yang menunjukan secara keseluruhan item visualization skills reliabel dengan Cronbrach Alpha sebesar 0,71. Namun konsistensi jawaban dari responden lemah. Visualization Skills siswa perlu ditingkatkan melalui model, metode, dan media visual yang mendukung keterampilan visualisasi.*

Kata kunci: *keterampilan visualisasi, rangkaian listrik arus searah, model 4D, analisis Rasch*

▪ INTRODUCTION

Visualization skills are skills to represent, transform, generalize, communicate, document, and reflect objects or things into visual information (Hershkowitz, 1989; Özkan et al., 2018). Visualization skills have a learning outcome "describe as the ability to picture three-dimensional shapes in the mind's eye" (Contero et al., 2006; Katsioloudis et al., 2014). Özkan (2018) defines visualization as a process of forming meaning, and in this process, various kinds of 2D objects can be used, such as pictures, figures, graphs, visual diagrams, and tables. According to Mnguni (2014), Visualization can be defined as the ability to select and use a set of cognitive skills to understand, process, and produce visual models. Based on this understanding, visualization skills can be defined as cognitive skills to understand, present, communicate, and document

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DOI: http://dx.doi.org/10.23960/jpmipa/v24i1.pp84-97
Received: 07 February 2023
Accepted: 26 February 2023
Published: 28 February 2023

an object in visual information. Visualization skills can be assessed through five aspects based on Mnguni's indicators (2021) in Table 1.

Table 1. Visualization skills

Skills	Definition
Analyze	To systematically break down an External Representation into essential features by making sense of and assigning scientifically correct meaning to its components.
Describe	To use content knowledge to provide a detailed, comprehensible account of scientific knowledge depicted in an External Representation.
Illustrate	To use an External Representation to describe or explain a scientific phenomenon
Infer	To use an External Representation to logically establish knowledge through deductive reasoning
Outline	To give the main features of scientific phenomena using an External Representation.

Visualization skills were previously developed by Mnguni in 2007 as part of visual literacy. Mnguni's (2007) research found that there is a gap in the literature regarding visual literacy based on the cognitive process of visualizing the concept of mitosis. Furthermore, research on further visualization skills by Mnguni (2019) and Mnguni et al. (2016) found that students had difficulty understanding visual information, and some students could not understand the meaning of the symbols used in representations. In addition, some students cannot interpret pictures or describe what is shown. Visualization skills research was also examined in orthographic projection learning, and it was found that students had difficulty understanding orthographic projection, especially those who had low visualization skills (Omar et al., 2019). Other research states that visualization skills are very important in learning mathematics, which is considered a combination of abstract concepts (Özkan et al., 2018).

Based on Mnguni's research (2019), Mnguni et al. (2016), Omar et al. (2019), and Özkan et al. (2018) it can be seen that visualization skills are needed in science learning. Physics is one of the sciences that requires a visual representation (shape or image) to make it easier to solve problems. Visualization skills must be developed in learning, especially in physics, where the learning material is abstract. Abstract concepts that require visualization can help students improve their understanding of the concepts being studied.

Previous research on visualization skills conducted by Mnguni (2016) developed an instrument test for visualization skills in biochemistry; Omar et al. (2019) used the PSVT: R test instrument as a measure of students' visualization skills; and Özkan et al. (2018) used an essay test instrument to measure students' visualization skills in mathematics. Therefore, it is necessary to develop an instrument to test visualization skills in learning physics, especially abstract concepts. One of the abstract concepts of physics is a direct current electric circuit. So this study aims to develop instrument test visualization skills on the topic of direct current electric circuits.

▪ METHOD

Participants

The participants in this research consisted of 33 high school students at a public high school in West Java. The selected participants are students who have received learning related to direct current electric circuit material. Students were selected by random sampling.

Figure 1. Maps of Banjaran, West Java – Indonesia
Source: https://goo.gl/maps/3d85Rid2KPEhfW6R6

Research Design and Procedures

The 4D model research approach on Figure 2, which entails defining, creating, developing, and disseminating, is employed based on this research. A literature review on visualization skills and a curriculum analysis of direct current electric circuit material are done during the defining stage. At the designing stage, the distribution of questions is carried out based on aspects of visualization skills and creating question indicators. Questions are created throughout the developing stage based on visualization skills, question indicators, evaluation rubrics, and expert instrument validation. Furthermore, the dissemination step is carried out by putting the questions to the students to determine the instrument's quality in relation to the validity, reliability, and level of difficulty of the item questions.

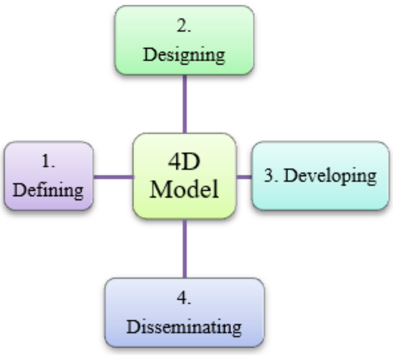


Figure 2. 4D Model scheme

Instruments

The instrument used in this reasearch is an instrument that corresponds to aspects of visualization skills (Analyze, Describe, Illustrate, Infer, and Outline. This instrument is in the form of an essay consisting of 11 questions. The distribution of questions in each aspect is presented in Table 2.

Table 2. Distribution of visualization skills instruments

Aspects of Visualization Skills	Question indicator	Item Number
Analyze	Analyze combined electrical resistor circuits to distinguish the amperage passing through each lamp and mark it with a picture of the lamp's brightness.	1, 2
Describe	Describe using visual images the differences in the movement of electrons in metal conductors that are placed at different electric potentials of different magnitudes.	3
	Describe using visual images the differences in the composition of the particles that make up metal objects that have different resistivity.	4
Illustrate	Illustrate by using visual images a series of electronic equipment in a household that are both installed at a voltage of 220 volts.	5
	Illustrate by using visual images the decrease in electric potential at points along a simple electric circuit	6
	Illustrate using visual images a decrease in the electric potential at points along a branching electric circuit	7
Infer	Inferring the speed of movement of electrons on the conducting wire of an electric circuit based on the forces acting on the electrons. The inferences taken are expressed in visual images.	8
	Inferring the velocity of electrons along a simple electric circuit based on the similarity of electric currents at points along the electric circuit. The inferences taken are expressed in visual images.	9
Outline	Stating an outline in the form of a visual image of a series resistor circuit so that the total resistance is large.	10
	Stating an outline in the form of a visual image of a parallel resistor circuit so that the total resistance is small.	11

Data Analysis

Data analysis used in this research consisted of four stages. The first stage is to analyze the results of expert validation using the CVR index with the following formula.

$$CVR = \frac{\eta_e - \frac{N}{2}}{\frac{N}{2}} \quad (1)$$

Information:
η_e : The total score for the response aspect of the assessment
N : Total maximum score of response aspects of the assessment

The CVR values obtained are interpreted based on the index criteria presented in Table 3. (Wilson et al., 2012).

Tabel 3. CVR category

Index Criteria	Score
-1.00 ≤ CVR ≤ 0.50	not appropriate
-0.50 ≤ CVR ≤ 1.00	appropriate

The results of the CVR calculation are used to determine the validity or invalid conclusion of each item that has been validated. then categorizing the validation results using the reference as listed in Table 4. (Wilson et al., 2012).

Table 4. Validation category

Assessment Criteria	Category
Index $CVR_{count} \leq CVR_{critical}$	Invalid
Index $CVR_{count} > CVR_{critical}$	Valid

The second stage determines to construct validity using Rasch analysis. Construct validity was seen from item dimensionality by looking at raw variance values explained by measures and unexplained variance 1st contrast (Lestari & Samsudin, 2020; Sumintono & Widhiarso, 2015). The third stage determines the suitability of the questions and the level of difficulty of each item analyzed using Rasch, which can be viewed from the perspective of statistical fit (Nurdini et al., 2020). The criteria used to analyze the suitability of these items can be seen in the fit order items by reviewing the MNSQ, ZSTD, and PT. Measure corr. outfit values. The fourth stage is to test the reliability using Rasch analysis. The instrument reliability test with Rasch analysis is based on several reliability values, such as person reliability, item reliability, and Cronbach's alpha. Person reliability shows the consistency of student answers, item reliability shows the quality of the test items, and Cronbach's alpha shows the value of the interaction between the person and the items of the test as a whole. The interpretation of the Cronbach alpha value is shown in Table 5. The interpretation of the value of person reliability and item reliability can be seen in Table 6. (Sumintono & Widhiarso, 2015).

Table 5. Interpretation of reliability test based on Cronbach Alpha value

Interpretation	Value
Very Good	r ≥ 0.8
Good	0.7 ≤ r < 0.8
Enough	0.6 ≤ r < 0.7
Bad	0.5 ≤ r < 0.6
Very Bad	r < 0.5

Table 6. Interpretation of person reliability values and item reliability values

The value of person reliability and item reliability	Interpretation
0.94 ≤ Value	Excellent
0.90 ≤ Value < 0,94	Very good
0.80 ≤ Value < 0,90	Good
0.67 ≤ Value < 0,80	Enough
Value < 0,67	Weak

▪ RESULT AND DISSCUSSION

The results and discussion of the development stages through the 4D model (defining, designing, developing, and disseminating) in DCEC-ViSIT will be discussed as follows.

Defining DCEC-ViSIT

In the defining stage of this research, literature studies related to visualization skills and curriculum analysis related to direct current electric circuit material were carried out. The results of the literature study show that visualization skills are cognitive skills for understanding, presenting, communicating, and documenting an object through visual information. Visualization skills can be assessed through five aspects: analyze, describe, illustrate, infer, and outline (Mnguni & Moyo, 2021).

Designing DCEC-ViSIT

At the designing stage, questions are made based on aspects of visualization skills, and question indicators and an assessment rubric are created. Table 7 shows indicators for each aspect of visualization skills.

Table 7. Indicator question visualization skills

Aspect	Questions Indicator
Analyze	1.1 Analyze the combined electrical resistor circuit to distinguish the electric current that passes through each lamp and mark it with a picture of the lamp brightness.
	1.2 Analyze the combined electrical resistor circuit to distinguish the electric current that passes through each lamp and mark it with a picture of the lamp brightness.
Describe	2.1 Describe using visual images the differences in the movement of electrons in metal conductors that are placed at different electric potentials of different magnitudes.
	2.2 Describe using visual images the differences in the arrangement of the particles that make up metal objects that have different resistivity.
Illustrate	3.1 Illustrate by using visual images a series of electronic equipment in a household that are both installed at a voltage of 220 volts.
	3.2 Illustrate using visual images the decrease in electric potential at points along a simple electric circuit.
	3.3 Illustrate using visual images the decrease in electric potential at points along a branching electric circuit.

Aspect	Questions Indicator
Infer	4.1 Inferring the speed of movement of electrons on the conducting wire of an electric circuit based on the forces acting on the electrons. The inferences taken are expressed in visual images.
	4.2 Inferring the velocity of electrons along a simple electric circuit based on the similarity of the electric current at points along the electric circuit. The inferences taken are expressed in visual images.
Outline	5.1 Stating an outline in the form of a visual image of a series resistor circuit so that the total resistance is large.
	5.2 Stating an outline in the form of a visual image of a parallel resistor circuit so that the total resistance is small.

The aspects and indicators shown in Table 7 are used as guidelines for the stages of making visualization skills questions. Furthermore, for the scoring rubric on each aspect of visualization skills, a score of 0–4 is used, as shown in Table 8.

Table 8. Visualization skills assessment indicator

Visualization Skills	**Score**	**Assessment Criteria**
Analyze	4	Answer contains all scientifically acceptable components.
	3	Answer contains several scientifically acceptable components.
	2	Answers show that the material can be understood but contains alternative material.
	1	Wrong answer, the scientific response contains information that is not logical or incorrect.
	0	Answer is blank
Describe	4	Can describe all components of a scientific description
	3	Can describe several components of a scientific description
	2	Can be described as partly scientific but also contains some unscientific information.
	1	Incorrect description
	0	Not describing
Illustrate	4	An image that reflects all components of a scientific depiction
	3	An image that reflects some of the components of a scientific depiction
	2	Images that reflect some scientific but also contain some unscientific
	1	The picture reflects a completely unscientific depiction
	0	Not drawing
Infer	4	Inferences are correct and scientifically acceptable.

Visualization Skills	Score	Assessment Criteria
	3	Inferences are less precise and scientifically acceptable.
	2	Inferences are understandable but contain alternative material.
	1	Wrong inference
	0	Do not make inferences.
Outline	4	The answer contains all scientifically acceptable components
	3	The answer contains several scientifically acceptable components.
	2	The answers show that the material can be understood but contains alternative material.
	1	Wrong answers and scientific responses contain information that is illogical or incorrect.
	0	Blank answer

Developing DCEC-ViSIT

In the developing stage, questions are made based on the five aspects of visualization skills and question indicators, which consist of 11 questions in the form of essays. Figure 3 shows one of the questions on the DCEC-ViSIT instrument.

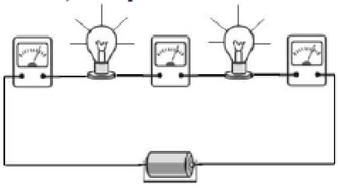
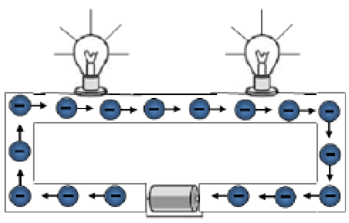
Aspect of Visualization Skills	Questions Indicator	Questions	Answer
Infer	Inferring the velocity of electrons along a simple electric circuit based on the similarity of electric currents at points along the electric circuit. The inferences taken are expressed in visual images.	The image below shows a reading of the electric current strength at various points in a simple electric circuit. It appears that the readings of the electric current are the same everywhere. The size of the electric current at a point in the circuit depends on the speed of movement of the electric charge carriers (electrons) at that point.  What can you conclude about the motion of the free electrons along the electric circuit? Describe your conclusions in the form of visual images!	Based on the similarity of the electric currents at points along a simple electric circuit, it can be concluded that the speed of the motion of electrons everywhere along a simple electric circuit is the same. 

Figure 3. DCEC-ViSIT item

After all the DCEC-ViSIT items were completed, the instrument was validated by experts. The validator makes an assessment based on the realms of material, construction, and language. From the results of the CVR calculation, overall, the test instruments that have been prepared are in the appropriate interpretation area in terms of material, construction, and language. to obtain valid or invalid conclusions for each item that has been validated by five experts (N = 5) with a critical CVR of 0.736 and a calculated CVR of 0.93 (CVRcount > CVRcritical). In line with Lawshe's opinion (Hidayati et al., 2022), a ratio value close to 1 indicates good or high validity. Other studies have found that a ratio value of more than 0 indicates the item is good (Yudhistira & Tomoliyus, 2020) so that it can be concluded that each item is valid to be used as a measuring tool for visualization skills.

Disseminating DCEC-ViSIT

At the disseminating stage, the implementation of the questions was carried out with students to find out the quality of the instrument related to the validity of the instrument, the reliability of the instrument, and the level of difficulty of the item questions. The validity of the instrument used, namely construct validity (unidimensionality), is presented in Figure 4.

Table of STANDARDIZED RESIDUAL variance in Eigenvalue units = Item information units

		Eigenvalue	Observed		Expected
Total raw variance in observations	=	27.6256	100.0%		100.0%
Raw variance explained by measures	=	16.6256	60.2%		59.7%
Raw variance explained by persons	=	3.2485	11.8%		11.7%
Raw Variance explained by items	=	13.3771	48.4%		48.0%
Raw unexplained variance (total)	=	11.0000	39.8%	100.0%	40.3%
Unexplned variance in 1st contrast	=	2.5350	9.2%	23.0%	
Unexplned variance in 2nd contrast	=	2.2123	8.0%	20.1%	
Unexplned variance in 3rd contrast	=	1.5694	5.7%	14.3%	
Unexplned variance in 4th contrast	=	1.3311	4.8%	12.1%	
Unexplned variance in 5th contrast	=	1.0684	3.9%	9.7%	

Figure 4. The results of the analysis of the construct validity of visualization skills

Based on the Rasch analysis in Figure 2, it can be seen that the raw variance of the data is 60.2% with a special interpretation. And the instrument test visualization skills have unexplained variance in the contrast of residuals from the 1st to the 5th: 9.2%; 8.0%; 5.7%; 4.8%; and 3.9%. The raw variance requirements explained by the measure are greater than 20% (Muslihin et al., 2022), with interpretation criteria met if between 20% and 40%; appropriate if between 40% and 60%; and fulfilled if it exceeds 60%. And the variance that cannot be explained by the instrument ideally does not exceed 15% (Rusmana et al., 2020). So, it can be concluded that the DCEC-ViSIT instrument is valid for assessing the visualization skills of high school students.

Then determine the quality of the questions and the suitability of the questions on the fit order items, as shown in Figure 5.

Item STATISTICS: MISFIT ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PTMEASUR-AL CORR.	PTMEASUR-AL EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Item
5	54	33	-1.13	.26	1.57	2.07	1.53	1.96	A .73	.54	48.5	54.2	V5
9	16	33	1.99	.34	1.35	1.37	1.43	1.56	B .12	.46	33.3	66.7	V9
2	82	33	-2.96	.25	1.34	1.40	1.37	1.50	C .19	.55	57.6	53.4	V2
11	15	33	2.11	.34	.97	-.03	1.00	.10	D .54	.45	66.7	67.6	V11
8	8	33	3.09	.42	.92	-.17	.87	-.19	E .37	.38	81.8	77.0	V8
3	43	33	-.35	.27	.84	-.59	.87	-.47	F .59	.52	51.5	58.4	V3
10	30	33	.67	.29	.83	-.69	.85	-.62	e .23	.50	72.7	57.7	V10
7	34	33	.34	.28	.81	-.74	.79	-.86	d .72	.51	57.6	56.7	V7
1	77	33	-2.64	.25	.77	-.99	.78	-.95	c .56	.55	60.6	53.9	V1
4	51	33	-.92	.26	.70	-1.32	.71	-1.24	b .69	.54	63.6	55.9	V4
6	41	33	-.20	.27	.63	-1.68	.60	-1.84	a .77	.52	75.8	58.2	V6
MEAN	41.0	33.0	.00	.30	.98	-.1	.98	-.1			60.9	60.0	
P.SD	23.0	.0	1.82	.05	.29	1.2	.30	1.2			13.0	7.0	

Figure 5. Item fit order for visualization skills

Based on Figure 5, it can be used to determine the quality of visualization skills questions, namely through the MNSQ, ZSTD, and PTMEASURE Corr. Outfit scores (blue boxes), and the level of difficulty of visualization skills questions through Measure and P. SD values (yellow boxes). The results of the item quality categories are presented in Table 9.

Table 9. Results of processing quality questions visualization skills

Aspects of Visualization Skills	**Item number**	**Outfit**		**PT. Measure Corr.**	**Interpretation**
		MNSQ	**ZSTD**		
Analyze	1	0.78	-0.95	0.56	Very appropriate
	2	1.37	1.50	0.19	appropriate
Describe	3	0.87	-0.47	0.59	Very appropriate
	4	0.71	-1.24	0.69	Very appropriate
Illustrate	5	1.53	1.96	0.73	Very appropriate
	6	0.60	-1.84	0.77	Very appropriate
	7	0.79	-0.86	0.72	Very appropriate
Infer	8	0.87	-0.47	0.59	Very appropriate
	9	1.43	1.56	0.12	appropriate
Outline	10	0.85	-0.62	0.23	appropriate
	11	1.00	0.10	0.54	appropriate

Table 9 shows that some of the items in the visualization skills questions are quality items that are included in the interpretation of "very appropriate" with a percentage of 64% and "appropriate" with a percentage of 36%. The criteria for fit-order items are shown in Table 10.

Table 10. Item fit order criteria

Criteria	**Value**
MNSQ	0.5 < x < 1.5
ZSTD	-2.0 < x < +2.0
Pt. Mean Corr	0.4 < x < 0.85

If these three criteria are met, then it can be said that the item is "very appropriate" so that the quality of the item can be ascertained to be good for use (Nurdini et al., 2020; Sumintono, 2018). It is said to be appropriate when only one or two criteria are met so that these items can still be maintained and do not need to be changed (Nurdini et al., 2020). Meanwhile, if the criteria are not met, the item is said to be "not appropriate," meaning it is not good enough and needs to be repaired or replaced (Nurdini et al., 2020).

Item fit order analysis for the level of difficulty of each item was carried out by analyzing the measured value (M) and standard deviation (SD) (Sumintono & Widhiarso, 2015), which are presented in Table 11.

Table 11. Processing results of visualization skills problem difficulties

Aspects of Visualization Skills	Item number	Measure	SD	Interpretation
Analyze	1	-2.64	1.82	Easy
	2	-2.96	1.82	Easy
Describe	3	-0.35	1.82	Medium
	4	0.92	1.82	Medium
Illustrate	5	-1.13	1.82	Medium
	6	-0.20	1.82	Medium
	7	0.34	1.82	Medium
Infer	8	3.09	1.82	Difficult
	9	1.99	1.82	Difficult
Outline	10	0.67	1.82	Medium
	11	2.11	1.82	Difficult

Based on Table 11, it can be seen that the level of difficulty of the questions, including the interpretation of "difficult" is around 27%, the level of difficulty is "moderate" with a percentage of 55%, and the level of difficulty is "easy" with a percentage of 18%. The difficulty level of the item is determined based on the measure value and standard deviation, with a difficult interpretation if the M value is greater than +1SD, moderate if the M value is between -1SD and +1SD, and easy if the M value is less than -1SD (Wati et al., 2019). Thus it can be concluded that the 11 items on visualization skills can be used and no questions are replaced.

In addition to the analysis of the validity and parameter analysis of the items, an analysis of the reliability of the instrument visualization skills was carried out. The results of the reliability analysis obtained by the test instrument (Cronbach alpha) were 0.71, which is included in the "good" category. while the value of person reliability is 0.66, which is included in the "weak" category, and the item reliability value is 0.97, which is included in the "special" category. So it can be concluded that the consistency of the answers from the respondents is weak, but the quality of the items in the instrument is special. Figure 6 shows a diagram of students' average scores on each aspect of visualization skills.

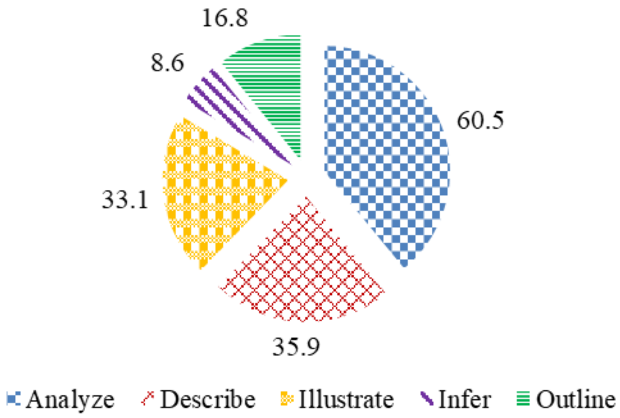


Figure 6. Students' average scores on each aspect of visualization skills

Figure 6 shows that the highest average student scores are on the analyzing aspect and the lowest on the inferring aspect. However, student scores are not ideal in every aspect of visualization skills. This shows that students still find it difficult to visualize the concepts being studied, especially abstract concepts. To make abstract phenomena more understandable to students, efforts are needed to visualize them in the form of models, simulations, or analogies that students can observe. Physics concepts that contain abstract phenomena require teaching media that can visualize these phenomena (Wibowo et al., 2017). A survey conducted by Semenikhina et al. (2021) on physics teachers shows that computer simulations are needed such as Phet, VirtuLab, LabVIEW, and others to explain abstract phenomena. This survey is further strengthened by research conducted by Bajpai & Kumar (2015), which states that the use of computer simulations such as Phet, Crocodile Physics, and Edison 4.0 can help students better understand abstract concepts. This is in line with Sarwono's research (2021), which states that for students to be able to visualize abstract physical phenomena, a variety of visual media is needed besides static images or photos. Based on previous research, it can be concluded that to improve students' visualization skills, models, methods, and various kinds of visual media are needed.

▪ CONCLUSION

The results of this research indicate that the developed DCEC-ViSIT instrument has good quality in terms of reliability and validity. Of the 11 items, visualization skills can be used, and no questions are replaced. The difficulty level of DCEC-ViSIT items varies. The visualization skills test instrument is feasible to be used as a measuring tool for high school students' visualization skills based on its validity, reliability, and level of difficulty. The results of using DCEC-ViSIT show that visualization skills need to be improved through visual models, methods, and media that support visualization skills.

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