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ARTICLE

Exploring senior high school students' preconceptions of collision concepts using visual representation

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Abstract

Understanding students' preconceptions is an important initial step towards meaningful and appropriate physics learning. Particularly in the concept of collisions, students' understanding of collision concepts often does not align with those established by scientists. Therefore, to explore students' preconceptions, visual representation enables students to connect their experiences with specific concepts. This aids in revealing and diagnosing students' preconceptions. This research aims to analyze high school students' preconceptions regarding collision concepts by examining their visual representations. The research design employs a qualitative descriptive research design with data collection methods including observation sheets and interviews. Observation sheets containing visual representations by students are analyzed using a four-step semiotic analysis approach, while interview data is analyzed thematically. Seventy-two tenth-grade students were sampled offline using convenience sampling. The research findings reveal that students' use of visual representations indicates diverse preconceptions about collision concepts, categorizing them at the macroscopic level. This data is examined across four categories of student visuals: (1) 11 visuals that are correct; (2) 18 visuals based on the objects used; (3) 34 visuals depicting different types of collisions; (4) and 29 visuals that are incorrect.

Keywords: Preconception, concepts of collision, visual representation

1. Introduction

Physics is one of the subjects that employs inductive thinking patterns and consistently examines materials through natural phenomena. To facilitate this, before learning begins, students should be directed to think about or imagine something related to the physics material to be discussed. One of the topics frequently encountered in everyday life is the phenomenon of collisions, which is covered in the concept of momentum. Collisions or collisions between two objects can be analyzed using the concept of momentum. Momentum itself is a study in mechanics that forms the foundation for the exploration of other physics concepts. In the context of investigating the concept of momentum, previous research revealed that 80% of students out of a total of 25 participants considered the conservation of momentum concept to only apply to perfect elastic collisions (Soeharto, 2013). Additionally, other research found that the law of conservation of momentum does not apply to completely inelastic collisions at all (Rikardo, 2008). From these two studies, it is evident that the understanding of collision concepts does not align with the concepts of the law of conservation of momentum as applied by scientists. In other words, the concept of collisions in momentum is considered simple but is, in fact, a complex topic. Therefore, students face difficulties in understanding and defining concepts related to collisions.

Several studies investigating collision concepts or the law of conservation of momentum have been conducted through tests, both in the form of multiple-choice and essay tests. In this context, the disclosure of students' conceptions regarding the concept of momentum is stimulated by problems provided by teachers after learning. In this context, there is rarely research that explores students' preconceptions in that specific context. Revealing preconceptions is crucial because it allows for an understanding of students' ideas before they receive a new concept. Each student has different initial concepts (preconceptions). However, sometimes students' physics concepts are based on experiences they have had, which may not necessarily align with the concepts of physicists. Students' understanding of physics concepts forms a range of preconceptions, from simple to complex, logical, consistent, and challenging to change. This indicates that before learning takes place, students bring with them a set of ideas or notions acquired previously. Therefore, in this case, there is a need to make an effort to understand students' preconceptions before learning physics. One approach is the use of visual representation, which can reveal students' preconceptions about abstract and mathematical concepts.

Although the use of visual representation is beneficial, there are some shortcomings in studies that utilize visual representation to explore students' understanding in general. First, teachers may have different interpretations or understandings of the visual representations produced by students compared to what students actually mean. Second, students may have difficulty replicating through visual representation what is in their minds Castro-Alonso, Ayres, and Sweller 2019. In an effort to bridge these gaps, visual representation can be used as a tool to investigate students' preconceptions of specific physics concepts, allowing these findings to be used by teachers to design visual representation-based learning. Moreover, visual representation is an important scientific process skill for the scientific method, especially in hypothesis formation, experimental design, analysis, data presentation, and communication of results (Schwarz, et al. 2009).

Several researchers have conducted studies on the use of visual representation in learning specific physics concepts. For example, Mujib Ubaidillah (2009) researched students' mistakes in creating visual representations of geometric optics concepts. The representation errors made indicate that the mastery of concepts related to geometric optics is still low. Additionally, Ian Phil Clas (2019) studied the use of visual representation in identifying students' preconceptions about the concept of friction. The research findings showed that the use of visual representation related to students' understanding of friction is at the macroscopic level. Both studies indicate that the use of visual representation is attractive to researchers in physics education because it is rarely used to explore students' preconceptions about specific concepts in physics.

2. Literature Framework

2.1 Concepts and Conceptions

Many experts define the concept in general as an abstraction that describes the common characteristics of a group of objects, events, or other phenomena. A concept is a unit of meaning representing a number of objects with similar characteristics (Rivai et al. 2021). Individuals with a concept can abstract objects studied, categorizing them into specific groups. Objects are presented in one's consciousness in the form of non-perceptual mental representations. A concept clarifies the knowledge found in a subject (Maryam 2020). Conceptual knowledge refers to understanding, definitions, specific characteristics, components, or parts of an object (Triyani et al. 2019).

From the opinions of experts above, it can be concluded that a concept is a representation used as characteristics to understand other things such as objects, events, or situations. Nawati (2017: 33) explains that conception is defined as opinions or understandings that already exist in the mind. Although in science classes most concepts have clear meanings, the learning conceptions differ. There are scientific conceptions, teacher conceptions, and student conceptions. Generally, scientific conceptions are considered the most comprehensive, reasonable, and widely used compared to other concepts, making them considered correct and widely accepted. Therefore, individuals may have different concepts from others due to different life experiences or interpretations.

2.2 Preconceptions

Preconceptions are initial concepts held by students formed from formal and informal experiences in daily life. This aligns with the constructivist view in learning, where students enter the learning environment with pre-existing preconceptions that will be reconstructed through social and physical interactions in the classroom as a result of the learning process. In the learning process, preconceptions can hinder students from understanding something because the focus is on students' concepts that differ from the actual concept, causing students to misdefine the concept. According to Suparno (2005: 34), preconceptions are ideas or notions held by students before receiving instruction inside or outside the classroom. When learning begins in the classroom, before students engage in the lesson, such as a lesson on mechanics, they already have many experiences with mechanical events, such as falling objects, moving objects, forces, and so on. Therefore, students have already formed many conceptions that may not be the same as physicists' conceptions. This is often overlooked by instructors in the learning process.

2.3 Visual Representation

Representation is something that symbolizes or represents objects and/or processes in this way (Rosengran, et al., 2007). Representation is a way used to express phenomena, objects, concepts, ideas, processes, or systems. The nature of representation is seen to influence the information presented and how people tend to interpret and remember presented information. Scientists use various representations to explain concepts, ideas, laws, systems, and processes. Representation is a way used to express phenomena, objects, concepts, ideas, processes, or systems (Ainsworth, Prain, and Tytler 2011). Explanation of scientific ideas and concepts, related to findings, uses verbal explanations, pictures, diagrams, or statements in mathematical form to make it easier for people to understand and more engaging. Scientists also modify or combine existing representations to explain an event or phenomenon.

Visual representation in textbooks can be presented in the form of pictures, diagrams, graphs, maps, and more. Visual learning tools play an important role in students' learning process because it directly influences students, particularly in the form of perceptions related to concepts (Asenova[1] and Reiss 2011). According to Wolff (2013: 39), visual representation holds a significant position in textbooks because a picture can represent thousands of words expressed by the author. Visual representation plays a crucial role in conveying material; foreign experts have conducted various studies and classifications of various types of visual representations. Various theories classify visual representation into different types, functions, and relationships with the content presented in textbooks.

Literature evidence shows that there are two purposes for using visual representation in teaching and learning: first, as a teaching pedagogy, and second, as an assessment tool. Multu's multimedia cognitive learning theory explains the important role of visual representation in the educational process. This theory outlines three stages of the visualization process in learning, including (1) understanding visual information, (2) processing information into cognitive structures, and (3) externalizing information as a visual model, such as visual representation. This explains that presenting images and words (produced vocally or written in text) simultaneously can enhance cognition and the construction of mental models, thus facilitating learning (Mutlu-Bayraktar, Cosgun, and Altan 2019).

One important reason related to the use of visual representation as a specific assessment tool in investigating preconceptions is that it allows students to establish connections between their experiences and specific concepts and gain insights from abstract concepts that cannot be observed. It enables students to concretely see how they can improve themselves (Cauley and McMillan 2010). When students produce their visual representations during assessment, the process itself helps improve and consolidate their learning; therefore, it can act as a tool for learning itself (Weurlander et al., 2012). However, in the actual teaching and learning process, students are often limited to explaining and interpreting ready-made visual representations provided by teachers. Almost never are they encouraged to develop their visual representations to demonstrate their understanding of the concept (Schukajlow et al. 2022).

Visual representation is also considered a powerful tool for thinking and communicating; therefore, it is possible to use it as an assessment tool in determining bias. It allows students to explicitly illustrate their thoughts before teaching, providing an opportunity for discussion and clarification. It reveals students' mental models and understanding, especially misconceptions, making it effective as a diagnostic, formative, and summative assessment. This may play a crucial role for teachers to address specific learning difficulties and measure students' understanding and achievements. Literature reports the use of visual representation as an assessment tool in biology, chemistry, geography, earth science, and physics (Quillin Thomas, 2015). Such assessments generally have two goals: as a diagnostic tool and to measure students' achievement in a subject (Corpuz and Rebello 2011).

3. Research Method

3.1 Research design

This research is designed using a qualitative descriptive research type (Doyle et al. 2020). Qualitative research is aimed at describing and analyzing phenomena, events, social activities, attitudes, beliefs, perceptions, and thoughts of individuals or groups. Several descriptions are used to find principles and explanations leading to conclusions. Qualitative research is inductive, meaning it allows problems to emerge from data or be left for interpretation. Among the important reasons for the Lambert Lambert (2012) design include (a) focusing on discovering the nature of specific events or phenomena being studied; (b) the research is in a highly naturalistic environment to avoid the Hawthorne effect where research participants behave differently knowing they are being observed (Cook 1962); (c) purposive sampling is intentional because the goal is to obtain information-rich cases; (d) data analysis does not need to follow pre-existing rules; (e) data presentation involves direct description and summary of the obtained information.

3.2 Participants

The population and sample objects targeted in the research have specific characteristics (Sundayana, 2020:15). The population for this study is tenth-grade science students at a high school in Garut Regency in the academic year 2022/2023. The sample consists of two tenth-grade science classes, with 36 students in each class, resulting in a total of 72 students. The sampling technique used in this study is purposive sampling because the researcher selects samples based on the predetermined research objectives (Sundayana, 2015:28). The participants in this study are 72 tenth-grade students with an age range of 15-16 years in a high school in Garut Regency. The selection of participants is based on the academic potential of students, with prior inquiries made to the respective teachers. Convenience sampling is used to select the school for this study, where the school is chosen based on accessibility, readiness, and availability.

3.3 Instruments

The research instruments used are observation sheets and interview guides. The first research instrument is an observation guide consisting of sheets of paper, as shown in figure (a), and writing tools to illustrate an object focused on a problem. For the first instrument, while in class, students are given paper and various drawing materials such as crayons, colored pens, and pencils. Without being given a definition or explanation, they are asked to freely draw a visual representation depicting a collision for approximately 25 minutes. This was intentional to not determine the scale (macroscopic, mesoscopic, microscopic) of the visual representation they should produce to determine the scale level they are most familiar with. The openness given to students to express their collision ideas through drawing during data collection is considered necessary to allow them to express as much and as deeply as possible their preconceptions about collisions. During this process, they are told that they can write descriptions, notations, or labels, and symbols in their drawings. They are instructed to work individually and are not allowed to consult with other students.

The second instrument is a semi-structured interview guide, including in-depth interview questions, which require long answers. During the interview process, the researcher will use recording tools such as a mobile phone recorder to record the interview results.

3.4 Data analysis

The data analysis method used in this study is thematic analysis after all the data is collected. Another study also suggests that for research on students' conceptions, thematic analysis can lead to the identification and categorization of preconceptions based on categories generated from codes, and the reliability of interpretation is crucial. In this study, because the data is in the form of visual representations or images, there are two analyses:

1. Analysis of Image Data: the analysis of image data uses a four-step approach developed (Baroutsis et al. 2019). This procedure can be summarized as follows: (a) annotation, where visual representations are reviewed, and notations are made, such as labeling objects/contexts depicted. (b) isolation, where visual representations are organized according to their interpreted meanings, detailed individual descriptions of visual representations are made (describing visual representations in narrative form, the length varies depending on the complexity of visual representations). (c) categorization, where visual representations are grouped into categories. (d) synthesis, where visual representations according to different categories are made.
2. Analysis of interview data: for interview data, the next step involves thematic analysis (TA). TA is a systematic method of data analysis that focuses on coding and theme development (meaning) and refers to research questions to present occurring phenomena (Castleberry and Nolen 2018). There are several phases for analyzing data thematically. Phase I involves familiarizing oneself with the data, where researchers can read interview transcripts repeatedly or listen to audio recordings, then make notes while reading or listening to highlight potentially interesting aspects. Notes can take the form of comments, transcript annotations, or underlining. Meanwhile, Phase II involves coding. Codes can identify data that potentially aligns with research questions and provide a brief summary of some data. Finally, Phase III involves theme identification. Theme identification is built based on previous codes related to the research phenomenon that will later form several themes. Then, relationships between existing themes are sought to form a complete story of the data and answer research questions. If there is a code or theme that does not fit the overall research, it will be replaced with a new theme.

4. Result of the research

This research shows the findings of students' thoughts or students' conceptions of physics material on the concept of collisions. The data for this study is derived from student observation sheets and interview results conducted by the researcher after students expressed their concepts through drawings. Based on the observations and interviews conducted, the research results on preconceptions of collisions through visual representations can be categorized into 4 categories: (1) correct collision concepts; (2) collision concepts according to objects; (3) concepts according to types of collisions; and (4) incorrect collision concepts.

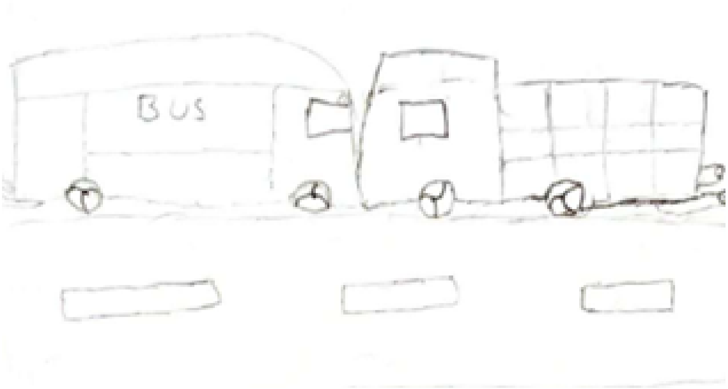

Figure 1. An image example of correct collision concepts

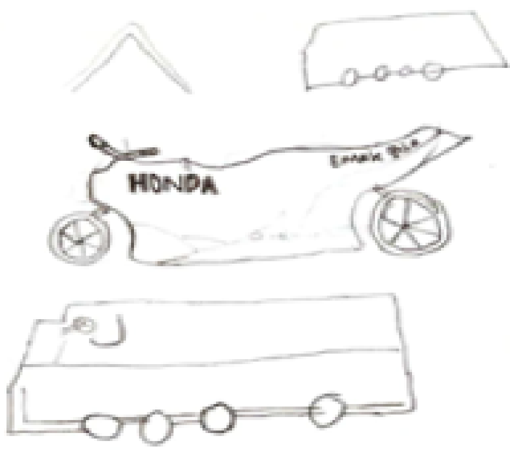

Figure 2. An image example of collision concepts according to objects

From the data obtained from the findings, it is evident that students have different preconceptions about the actual concept of collisions. The visual results of students' preconceptions can be categorized into four groups: (1) correct collision concepts; (2) collision concepts based on objects; (3) concepts based on the type of collision; and (4) incorrect collision concepts. Among these categories, students' visual representations fall into the macroscopic level, reflecting their everyday observations that often involve large-sized objects visible to the human eye. This aligns with the findings of previous research (Batlolona, Diantoro, Leasa, et al. 2020; Canlas 2021), suggesting that it makes sense for 10th-grade students to produce visual representations at the macroscopic level due to their cognitive maturity level, especially considering that participants may be introduced to physics at the high school level.

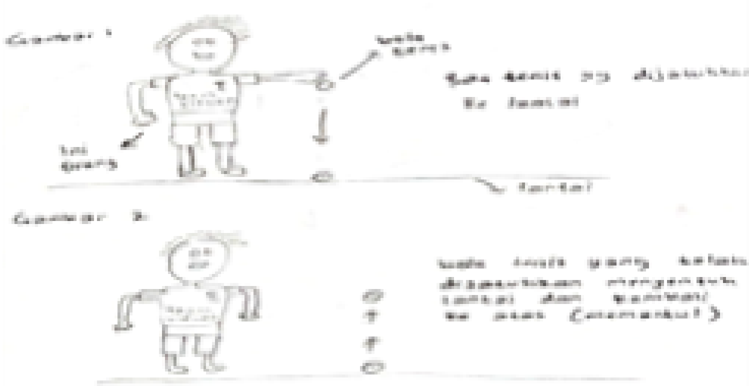

Figure 3. An image example of concepts according to types of collisions

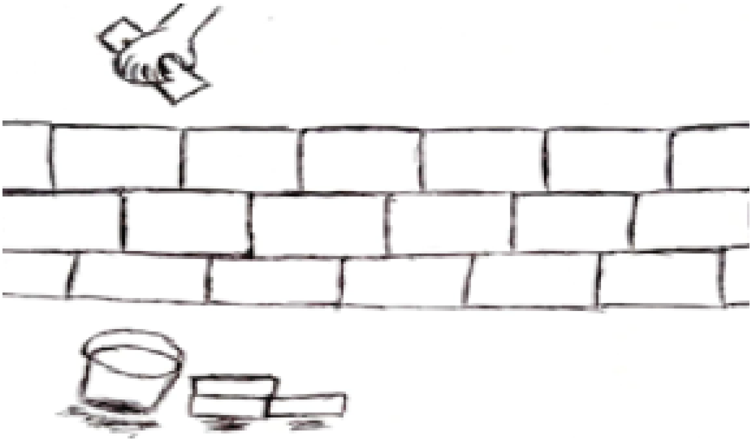

Figure 4. An image example of incorrect collision concepts

In the first category regarding correct collision concepts or concepts aligned with scientific principles, students demonstrated attention to detail when visualizing collision concepts. This aligns with the characteristics of visual accuracy described (Schreiber, Eisert, and Meyer 2023), indicating that students possess a precise visual understanding. This suggests that students closely relate to events or objects in their daily lives, potentially gained through observing or experiencing accidents involving moving objects. This experience enables students to visualize collision concepts accurately, consistent with previous research indicating that most students visualize collision examples that are accurate and consistent with scientific concepts (Abd-El-Khalick and Lederman 2000).

In the second category regarding the objects used during a collision event, it was found that students used various objects to visualize collision concepts, including vehicles. This aligns with previous research indicating that visual representations significantly aid in symbolizing or representing objects (Rosengran, et al., 2007). This finding is reinforced by Rohaeti, et al. (2019), showing that the use of objects can facilitate students in understanding more realistic and meaningful concepts.

In the third category regarding collision concepts according to the type of collision, two types of collisions were identified: elastic and inelastic collisions. Many students visualized elastic collisions, represented by a pendulum ball. This aligns with previous research showing that many students have difficulty visualizing inelastic and elastic collision types when understanding collision visuals (Can and Yaman, 2010). Similar challenges were reported in other studies, indicating that many students misunderstand and struggle to apply collision types in different scenarios (Yalcinkaya and Demisbas).

In the fourth category regarding incorrect collision concepts, students visualized collision concepts that did not align with the correct scientific concept; the visual representation had no connection to the concept of collision. This aligns with previous research revealing that many students have visual conceptions that do not match the actual concept of collision, and students face difficulty applying collision concepts in complex real-world situations (Sing and Ratan, 2014). This finding is similar to previous research indicating that many students have visual conceptions that do not align with the actual concept, with student errors influenced by factors such as experiences in their environment (Tanner and Shafffer, 2011).

In summary, students' preconceptions fall into the macroscopic level, which is relevant before the transition from concrete everyday experiences to abstract and more detailed understanding. This suggests that, for this group of students, some participants describing collisions can produce reasonably accurate and consistent understanding. Efforts should be made to advance their understanding at the mesoscopic and microscopic levels (Besson and Viennot 2004). It may be necessary for teachers to intentionally provide activities and examples at the mesoscopic and microscopic levels. It may also be crucial to explicitly provide activities and examples illustrating the differences among these three levels. Using real objects may help differentiate between the macroscopic and mesoscopic levels, but it is not feasible for the microscopic level. Therefore, using simulations or enlarged photos showing molecular-level interactions can be helpful. Furthermore, despite the events and occurrences seen or experienced by students in their experiences, preconceptions about collisions remain limited. This is evidenced by the incorrect visual representations drawn by students. Even for visual representations that are unclear or incorrect, it is uncertain whether the object or item is a collision or not. The results of this research reveal that there are still many misconceptions among students regarding the concept of collisions, and these misconceptions fall into the macroscopic level.

5. Discussion

The findings indicate that students have varying understandings of the concept of collisions. There are four categories of visual representations of students' preconceptions: correct collision concepts, collision concepts based on objects, collision concepts based on types, and incorrect collision concepts. The majority of students' visual representations fall into the macroscopic level, rooted in everyday experiences with large objects that can be directly observed. Students who visualize collision concepts correctly demonstrate detailed and meticulous understanding. They are able to connect the concept to events or objects in daily life, often through observation or direct experience with the collision between two moving objects. This aligns with previous research showing that a significant number of students can visualize collision concepts accurately.

In the category of collision concepts based on objects, students use specific objects, such as vehicles, to represent collision concepts. Previous research also suggests that visual representations can help students understand concepts more vividly and meaningfully through the use of objects. In the category of collision concepts based on types, two types of collisions identified by students are elastic and inelastic collisions. Many students find it easier to visualize elastic collisions compared to inelastic collisions. Previous research has also revealed students' difficulties in visualizing both types of collisions. The last category is incorrect collision concepts, where students cannot accurately depict the concept of collisions. Their visual representations lack relevant connections to the concept of collisions. This aligns with previous research indicating that many students have misconceptions and difficulties applying collision concepts in complex real-world situations.

Overall, students' preconceptions about collisions tend to be at the macroscopic level before they acquire a more abstract and detailed understanding through experiences and learning. Further efforts are needed to advance students' understanding to a deeper level. Teachers can provide activities and examples at more detailed levels, such as the mesoscopic and microscopic levels, using simulations or enlarged photos to help students understand molecular-level interactions. Moreover, students' biases about collisions are still limited, as indicated by incorrect visual representations. There are still many misconceptions among students about collision concepts, especially at the macroscopic level.

6. Conclusion

From the analysis and discussion in the research on exploring preconceptions of collision concepts using visual representations, it can be concluded that in this study, it was found that students have different preconceptions about collision concepts. Based on the visual representation results, students' preconceptions can be categorized into four groups: (1) correct collision concepts. This category indicates that students show attention to detail when visualizing collision concepts and have a precise and accurate visual understanding. (2) collision concepts based on objects. This category shows that the use of objects can help students understand concepts more vividly and meaningfully. (3) concepts based on the type of collision. This category indicates that students have difficulty distinguishing between inelastic and elastic collision types when understanding visual representations in collision concepts. (4) incorrect collision concepts. This category shows that many students have visual errors that do not align with scientific concepts. From these four categories, the research results on students' preconceptions fall into the macroscopic level, reflecting their everyday observations that often involve large objects visible to the human eye.

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