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ARTICLE

Analysis of diagrams in the kinetic gas theory materials in high school physics textbooks: a content analysis

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Abstract

The theory of gas kinetics material studies objects that are abstract in nature. Therefore, its learning requires visual representations capable of visualizing these abstract objects, one of which is diagrams. The presence of diagrams in high school physics textbooks is considered important to aid the learning process. This research aims to determine the distribution of diagram categories, trends in diagram usage, and teachers' perceptions of diagram usage in the Theory of Gas Kinetics material in high school physics textbooks with a descriptive quantitative research design. The research results show the distribution of diagram categories with the highest percentage in each analyzed book being the glossary image category, accounting for an overall percentage of 45%. The usage trends of each diagram category tend to fluctuate from year to year. Based on the findings of this research, teachers' perceptions of diagram usage in the Theory of Gas Kinetics material have three main themes: diagrams are important as learning aids to make lessons more interesting and to represent the identity of science, especially physics; the use of diagrams depends on teachers' needs; and diagrams help students understand the text and present physics concepts more specifically.

Keywords: Kinetic gas theory, physics textbooks, content analysis

1. Introduction

Studying and explaining the characteristics and behavior of objects in the universe is the focus of physics. In its discussion, physics covers various types of objects in the universe, such as point objects, rigid bodies, elastic bodies, fluids (liquids and gases), and invisible objects. Physics discussions on invisible objects explain the characteristics and activities of objects that are difficult to see directly with the human eye.

In the context of the learning process in schools, the ability to visualize the concepts being learned is crucial to facilitate students' understanding to be more realistic. Demonstrations delivered by teachers are sometimes not well understood by students, especially when the material involves abstract concepts (Siahaan et al., 2020). Multi-representational presentation of material is considered more effective in helping students understand and develop their abilities in solving mathematical problems (Hwang et al. 2007). Representation formats include verbal representations like discussions, presentations, or writings; visual representations such as images, graphs, tables, diagrams, simulations, and animations; symbolic and mathematical representations; as well as practical activities in the laboratory (Siahaan et al., 2020).

Visual representation, including diagrams, in textbooks plays a significant role in conveying learning materials designed to be engaging and systematic to achieve learning objectives. In textbooks, the presence of diagrams helps map the material to facilitate student understanding. Representations in textbooks, such as diagrams, graphs, equations, and tables, are central to the development of scientific meaning. These representational features are part of the science curriculum found everywhere, including science or physics textbooks. Research on visual representations in current school science textbooks is evolving (Vojíř and Rusek, 2019), primarily due to the increasing appeal of visual representations in contemporary textbooks (Slough et al., 2010). Previous research has focused on linguistic features in science textbooks, with little attention to non-verbal representations (e.g., diagrams) (Bryce 2013).

A diagram is a visual or schematic representation that depicts various aspects of an object or physical process (LaDue, Libarkin, and Thomas 2015). Diagrams are crucial representations for use in science education. The diagrams used in textbooks not only show various amounts of abstract information but also eliminate irrelevant details from the taught concepts. Additionally, diagrams can illustrate scientific phenomena and processes that are invisible to the naked eye. Therefore, the assistance of diagrams in science or physics textbooks is needed to visualize the concepts of these abstract objects. One such physics topic related to abstract objects is the Theory of Gas Kinetics. Therefore, the availability of diagrams in textbooks that visualize abstract concepts from the Theory of Gas Kinetics is very helpful in the learning process.

The abstraction of concepts in the Theory of Gas Kinetics material, which is difficult to visualize, requires facilities and infrastructure that can facilitate the learning process. However, the lack of modern instructional technology, inadequate classroom facilities, and insufficient training programs for teachers are common challenges in most public schools (Badmus and Jita 2022). The presence of diagrams in textbooks provides a solution to these limitations, helping teachers convey abstract concepts more clearly when using diagram visualizations in the learning process. Although the use of diagrams is useful in assisting physics teachers, empirical evidence regarding teachers' awareness of using diagrams in textbooks during the physics learning process, especially in the Theory of Gas Kinetics material, is rarely revealed in science or physics education research. Therefore, this study aims to uncover how diagrams are represented and how physics teachers perceive the importance of diagrams in the learning process of the Theory of Gas Kinetics.

Based on the above description, the author specifically aims to analyze the content and distribution of various types of diagrams in high school physics textbooks, especially in the Theory of Gas Kinetics material. Thus, the author chose the title "Analysis of Diagrams in the Theory of Gas Kinetics Material in High School Physics Textbooks."

2. Literature Framework

2.1 Physics textbooks in Indonesian science curricula

The 2013 Curriculum aims for students to have scientific work competencies, including formulating problems, proposing and testing hypotheses, determining variables, designing and conducting experiments, collecting and processing data, drawing conclusions, and communicating orally and in writing (Kemendikbud, 2016). In the science curriculum, one of the most important elements in learning is the textbook, which serves as the main teaching material for students in every subject at school. Particularly in physics education at high schools, textbooks play a crucial role as the primary teaching material that supports each physics learning topic.

Moreover, in the implementation of the 2013 Curriculum, most teachers choose to rely on the use of textbooks as the main teaching material. Therefore, there are already many high school physics textbooks available to facilitate learning activities, both specifically designed for teachers and for students. Generally, in the learning process, teachers heavily rely on textbooks to determine what will be presented in the material being studied (Abed and Al-Absi 2015). Thus, the quality of textbooks has a significant impact on the quality of teaching a particular subject or topic.

Textbooks with good quality are considered capable of helping improve students' competencies in the science curriculum. With the widespread availability of textbooks, the selection of the quality of these books needs to be enhanced. So that the available textbooks are truly of high quality. Therefore, textbooks with good quality must be designed in such a way that the presentation of concepts can be well understood by students. Through the National Education Standards Agency (Poerwanti 2008), the government has established standards for the feasibility of textbooks used, including content suitability, presentation, language, and graphics (BSNP, 2016). The availability of graphics, including diagrams, can help improve the quality of the textbook content by visualizing physics concepts that are difficult to visualize, making them easier to understand.

2.2 Diagram in physics textbooks

Although being a primary source of teaching material, textbooks can be one of the causes of misconceptions experienced by students, in addition to the students themselves, the delivery of material by the teacher, context, and teaching methods. This is because most students find it difficult to understand material explanations in textbooks through verbal communication alone. Visual representations are considered capable of supporting the content in textbooks to be more understandable. Many researchers show that the integration of visual learning representations into science discussions can facilitate students in understanding the scientific content they learn, including pictures, diagrams, tables, graphs, models, maps, and more (Cheng and Gilbert 2014; Cox 2005; Danish and Enyedy 2007; Guo et al. 2020). Physics concepts that deal with abstract objects will be difficult to understand if conveyed only through verbal representations in textbooks, one of which is the concept of the theory of kinetic gas. Therefore, visual representations that can visualize these abstract concepts are needed to be conveyed clearly.

There are several perspectives in classifying visual representations used in science textbooks. For example, Pozzer and Roth (2003) categorized all types of illustrations in science textbooks on a continuum from less abstract to most abstract, including photos, naturalistic images, maps and diagrams, graphs and tables, and equations. Photos are considered to convey some details, making them a strong representation of real-world phenomena. Naturalistic images are almost similar to photos, but some details of objects in the image are eliminated. Both photos and naturalistic images are isomorphic with the objects they depict (Arsenault, Smith, and Beauchamp 2006); representations provided by photos or naturalistic images can be understood by students and laypeople. Maps and diagrams eliminate irrelevant details but can depict objects or processes operating on a scale not visible to the naked eye or requiring additional interpretation by the reader (Houts et al. 2006). As diagrams vary widely, learners are required to interpret abstract visual conventions and realistic details correctly (Butcher 2006). Graphs and tables generally show relationships between items or steps in a process. Graphs and tables come in various forms, such as line diagrams and histograms. Equations are useful for representing the most abstract information, such as symbols representing quantities in physics. These diagrams can be presented in combination when illustrating scientific concepts.

In building the categorization of diagrams proposed by (Hegarty, Carpenter, and Just 1991), Hegarty emphasizes the importance of teaching diagrammatic literacy to enhance students' learning of scientific concepts. Earlier, Hegarty et al. had researched the use of diagrams in a scientific context, particularly in biology textbooks, and categorized scientific diagrams into three categories, including:

1. concrete objects where the spatial relationships in the diagram are isomorphic with objects in the reference. Since iconic diagrams show objects they represent, iconic diagrams are considered

effective in helping students recognize various types of physical systems not available for visual inspection (Hegarty et al., 1991). Iconic diagrams provide an outline that can help clarify differences.

2. Iconic diagrams, referring to the accurate depiction of Schematic diagrams, which are highly abstracted diagrams of real-world entities but do not maintain the physical relationships presented in the source information, such as electrical circuit diagrams and magnetic field diagrams (Lynch 1990).
3. Charts and graphs, which depict a set of interrelated one another, especially quantitative data and numerical meanings based on the interpretation of independent variables. Students need to identify all independent variables before making interpretations because abstract meanings and numerical data are included in charts and graphs.

2.3 Graphical Protocol Analysis

The analytical framework used in this research is based on the Graphical Analysis Protocol (GAP) according to Slough (2010).

2.3.1 Graphs should be considered based on their form and function

Although interconnected and often considered the same, the form and function of graphical representations are two distinct descriptors. Therefore, it is important to consider both aspects to assess the use of graphs in science textbooks. The classification system of graph types is currently unorganized (Vekiri, 2002). At the highest classification level, terms such as overall visual display, graphics, graphic display, and graphic representation are often used interchangeably in the literature, while other researchers such as Roth (1999) choose unique terms like scientific captions, and others like choose the term image (Kress and Van Leeuwen 2020).

2.3.2 It must help readers construct a mental model of a system

In previous research, it has been argued that a mental model is actually imaginative and not image-based (Pylyshyn, 2002). Imaginative representations retain visual and physical features of an object or experience, but they themselves are not visual. Mental models have been described as abstract internal representations of concepts and ideas that store spatial, physical, and conceptual features useful for decision-making (Rapp, 2005). For example, a mental model of a car would be much more complex than a mental image of a car and may involve abstractions about the time and distance a car can travel. The imaginative nature of these mental models indicates that both are useful and necessary for conceptual or visual/spatial system considerations. Diagrams have two main roles in illustrating a system, highlighting the parts of a system and highlighting the processes of that system. In static diagrams, parts of a system are usually depicted using labels that are words or phrases and are often connected to visual representations using lines or arrows to feature components (Pappas 2006).

To help students build a mental model of a system, Mayer conducted a series of experiments concluding that the components of devices and actions of each should be illustrated or labeled. For each experiment, there were illustration conditions, including no illustration/control; illustration with labels on device parts (i.e., parts), illustration with labels on main part actions (i.e., steps), and illustration with labels on step parts (Arsenault, Smith, and Beauchamp 2006; Mayer and Sims 1994).

2.3.3 Graphics and text must be physically integrated

Based on Mayer's research, students perform best in completing tasks when text and illustrations are placed close together on one page, compared to being placed separately, and consider this as a proximity-space principle (Mayer and Sims 1994). Other eye movement research shows that readers need to constantly refer between text and illustrations (Hegarty et al., 1996), and placing two sources of information side by side can facilitate attention shifts. Furthermore, it is suggested that placing images before text can activate existing background knowledge and schemes (Peeck, 1993).

2.3.4 Graphics and text must be semantically integrated

Through his research, researchers found that high school readers considered certain diagrams too difficult to understand. Increased text captions can facilitate graphic learning. Additionally, additional questions supporting science charts have a strong effect on making chart materials easier to learn. Questions can selectively focus students' attention. Similarly, Reinking et al. (1988) demonstrated that providing instructions on visual representation in integrating textual graphic information and making graphics more useful (Holliday and Benson 1991). Textbook designers should include more explicit signals or instructions in the text on how text and graphics are integrated. This has the potential to increase the amount of time spent observing illustrations. The Graphical Analysis Protocol (GAP) for graphs, using definition and coding, allows researchers to code each graph. With numbering in cases of multiple graphs, where each graph will be given a page number and letter (for example, 4a, 4b, etc.). The numbering will start from the top left of the page and continue clockwise.

3. Research Method

3.1 Research design

The research design employed in this study is a descriptive quantitative research design. Descriptive quantitative research is a type of research that analyzes data by describing the collected data (Segara, 2020). Content analysis in this study requires systematic reading and categorization of parts of diagrams, images, photos, and texts that appear in the eleventh-grade high school physics textbooks in the kinetic gas theory material. To have a more comprehensive understanding of the use of textbook diagrams, an interpretative paradigm is used in this research. Based on the description, the researcher utilizes a descriptive statistical approach in this study to analyze diagrams in the kinetic gas theory material in eleventh-grade high school physics textbooks.

3.2 Book samples and Participants

The population in this study consists of all physics chapters in the eleventh-grade high school physics textbooks. Meanwhile, the sample in this study includes one chapter on the kinetic gas theory in the eleventh-grade high school physics textbook and eleventh-grade high school students. For sample selection in this study, the researcher uses purposive sampling technique. The selection of the kinetic gas theory material in the eleventh-grade high school physics textbook is based on several reasons. First, students tend to have difficulty understanding abstract physics concepts, including the kinetic gas theory material, resulting in misconceptions among students. Second, the abstraction of concepts in the kinetic gas theory must be effectively conveyed in learning, including visualization through diagrams in the textbooks used. This can assist teachers in teaching the kinetic gas theory material, which is challenging to demonstrate directly.

Table 1. Book Identities

Book codes	Authors	Publishers	Published years	Chapter samples
1	Marthen Kanginan	Erlangga	2014	Kinetic theory of gas (C-8)
2	Ketut Kamajaya, Wawan Purnama	Grafindo Media Pratama	2016	Kinetic theory of gas (C-6)
3	Indarti, Aris Prasetyo, Naila Hilmiyana	Mediatama	2016	Ideal gas dan Kinetic theory of gas (C-6)
4	Marthen Kanginan	Erlangga	2017	Kinetic theory of gas (C-6)
5	Ni Ketut Lasmi	Erlangga	2017	Kinetic theory of gas (C-6)
6	Nor Shalina Saputri, Rahmat Riyadi	Mediatama	2021	Ideal gas and Kinetic theory of gas (C-8)

All eleventh-grade high school physics textbooks selected as samples in this study follow the 2013 revised curriculum. The information regarding the physics textbook samples in this study is presented in Table 3.1. The participants involved in this study are two physics teachers at one public high school in Garut regency, with the criteria of having used one or all of the textbooks analyzed by the researcher in this study. The first participant is a physics teacher for both tenth and eleventh grades. He holds a bachelor's degree in physics education and a master's degree in physics teaching, with 14 years of teaching experience. The second participant is an eleventh-grade physics teacher with a bachelor's degree in physics education and 16 years of teaching experience.

3.3 Instruments

The research instrument is a tool used by researchers to collect research data so that the research activities can proceed effectively and systematically. In collecting interview data, the research instrument in this study is a set of structured interview protocols. An interview is a research instrument that collects data orally from respondents to obtain the necessary information. To make it easier to understand and achieve the research objectives, the researcher needs to develop an interview protocol. According to another researcher (Krueger 2014), an interview protocol can be divided into several sections, including opening questions, introduction, transitions, key questions, and closing questions (McTigue and Slough 2010).

Meanwhile, to collect research results from textbooks, there is a need for the development of an analysis tool based on the Graphical Analysis Protocol (GAP) (Slough and McTigue, 2010). There are four main principles in GAP, including graphs should be considered based on their form and function, graphs should help readers build a mental model of a system, graphs and text should be physically integrated, and graphs and text should be semantically integrated.

3.4 Data analysis

Data analysis for processing visual representation data in this research uses descriptive statistics for each textbook, including the textbook titles and the number and proportion of each type of diagram. Descriptive statistics is a method of data analysis that involves collecting, describing, and processing numerical data, then interpreting it with interpretation or notes (Vivi, 2020). The data obtained from the research is random or raw data, so data analysis is needed to process this data into organized data (array data).

The organized data (array data) is grouped based on points (ungroup data). Data is grouped based on data groups (group data). Grouping data based on intervals or groups is data grouped based on specific data groups. The data and frequencies obtained are processed into a frequency distribution table to facilitate the calculation of the average number of diagrams that appear on each page in the Kinetic Gas Theory material. The data analysis in this research goes through several steps, including:

1. All diagrams in the textbooks are examined and coded. The coding criteria follow the definitions of 12 types of diagrams (photo, naturalistic image, stylized image, image glossary, scale diagram, flowchart - cycle, flowchart - stage, cross-section, map, table, graph/histogram, hybrid) proposed by Slough (McTigue and Slough 2010). The researcher and one other reviewer act as independent reviewers who cross-check the content analysis results to improve the reliability between the evaluators of the research. Agreement was reached on the criteria used to classify diagrams, such as specified characteristics, so that specific diagram types could be determined. Each disputed diagram was re-examined. A decision was reached when the reviewer had an agreement above 60%.
2. Calculate the frequency of each type of diagram that appears in each book. Calculate the average presence of diagrams for each page of the eleventh-grade high school physics textbook on the Kinetic Gas Theory chapter.

3. Summarize the trends in the use of diagrams in various categories in the Kinetic Gas Theory material in each analyzed high school physics textbook.

To process interview data, the researcher uses thematic analysis to obtain themes from each interview conducted by the researcher with the participants. The interview process is recorded for documentation and helps the researcher create interview scripts in more detail. After conducting interviews with participants, the results are written in the form of verbatim transcripts, which write the interview results in complete word-for-word or all recorded conversations from video/audio recordings (Harper 2011). Through the interview transcripts, the researcher analyzes using thematic analysis to obtain themes from each interview question with both participants.

Thematic analysis steps in the interview results in this research include: writing down each question asked by the researcher to the participants during the interview; quoting each participant's answer to each question; writing open codes for each text quote that represents the essence of each participant's answer, and describing these open codes into a theme for each question.

4. Result of the research

Various types of diagrams play different functional roles in physics learning, especially in the Kinetic Gas Theory material. Each type of diagram has its own unique characteristics in conveying specific information according to the type of information to be conveyed. A total of 101 graphical representations were analyzed in the Kinetic Gas Theory material in six eleventh-grade high school physics textbooks. Based on the research conducted, from various diagram categories in textbooks, the glossary of images is the most common diagram type, accounting for 45% of the total diagrams. It is then followed by the categories of naturalistic images and stylized images, each with a percentage of 14%. After understanding the composition of each diagram category in the six physics textbooks analyzed, the next step is to report the percentage differences for each type of diagram category in each analyzed textbook, considering different authors, publishers, and publication years. The data from the analysis will be sorted based on the high school eleventh-grade physics textbooks, from the oldest to the newest.

Table 2. Frequency and percentage of diagrams in the textbooks

Types of diagrams	Samples of books [frequency]						Total	Percentage
	B-1	B-2	B-3	B-4	B-5	B-6		
Photo	5	2	6	5	0	10	18	11%
Naturalistic images	6	4	5	8	0	5	23	14%
Stylized image	5	3	4	6	1	4	23	14%
Image glossary	11	9	17	14	4	19	74	45%
Scale diagram	0	1	1	0	0	1	3	2%
Flowchart - cycle	0	0	0	0	0	0	0	0%
Flowchart - stage	0	0	0	0	0	0	0	0%
Cross-section	0	0	0	0	0	0	0	0%
Map	0	0	0	0	0	0	0	0%
Table	0	0	3	1	0	0	4	3%
Graph/histogram	1	3	5	1	3	5	18	11%
Hybrid	0	0	0	0	0	0	0	0%

From the analysis results, it can be concluded that the dominating diagram category in the book is the glossary of images with a percentage of 39%, and it has a frequency of 11 out of the total 17 diagrams analyzed. The second dominating diagram category in the book is naturalistic images with a percentage of 21%, and it has a frequency of 6 diagrams falling into this category. For the photo and styled image categories, each has an equal percentage of 18%, with each having a frequency of 5 in the book. 4% of the total diagram distribution is attributed to the graph/histogram category with a frequency of 1. As for the scale diagram, flowchart-cycle, flowchart-stage, cross-section, map, table, and hybrid categories, each is not present in this book, so the percentage for each of these categories is none with a frequency of 0. The second book analyzed by the author is published by Grafindo, authored by Ketut Kamajaya and Wawan Purnama, published in 2016. The distribution of analyzed diagrams in this book can be seen in the following table. From the analysis results, it can be concluded that in the textbook, the dominating diagram category is the glossary of images with a percentage of 41% and a frequency of 9 out of the total 12 diagrams analyzed. The second dominating diagram category in the book is naturalistic images with a percentage of 18% and a frequency of 4. For the styled image and graph/histogram categories, each has the same percentage of 14% with a frequency of 3 each. For the photo category in this textbook, it has a percentage of 9% with a frequency of 2. And a percentage of 4% for the scale diagram category with a frequency of 1. For the flowchart-cycle, flowchart-stage, cross-section, map, and hybrid categories, they have a percentage of 0% with a frequency of 0, meaning that these diagram categories are not present in the material on the Kinetic Gas Theory in this book.

The third book analyzed in this study is published by Mediatama, authored by Indarti, Aris Prasetyo, and Naila Hilmiyana, published in 2016. The distribution of analyzed diagrams in this book can be seen in the following table. In this book, the dominating diagram category is the glossary of images with a percentage of 42% and a frequency of 17 out of the total 23 diagrams analyzed. The second dominating diagram category in this book is photos with a percentage of 15% and a frequency of 6. For the naturalistic image category and the graph/histogram category, they have the same percentage of 12% with a frequency of 5 each. The styled image category has a percentage of 10% with a frequency of 4, and the table category has a percentage of 7% with a frequency of 3. The category with the least frequency is the scale diagram with a percentage of 2% and a frequency of 1. In this book, for the flowchart-cycle, flowchart-stage, cross-section, map, and hybrid categories, they have a percentage of 0% with a frequency of 0 because these diagram categories are not present in the material on the Kinetic Gas Theory in this book.

The fourth book that the author analyzed is published by Erlangga, written by Marthen Kanginan, published in 2017. The distribution of analyzed diagrams in this book can be seen in the following table. Based on the analysis results shown in the table above, the dominating diagram category in this book is the glossary of images with a percentage of 40% and a frequency of 14 out of the total 21 diagrams analyzed. The second dominating diagram category in this book is naturalistic images with a percentage of 23% and a frequency of 8. Furthermore, the styled image category has a percentage of 17% with a frequency of 6, and the photo category has a percentage of 14% with a frequency of 5. For the table and graph/histogram categories, each has a percentage of 3% with a frequency of 1. In this book, the scale diagram, flowchart-cycle, flowchart-stage, cross-section, map, and hybrid categories each have a percentage of 0% with a frequency of 0, which means that there are no diagrams with these categories in this book.

The fifth book that the author analyzed is published by Erlangga, written by Ni Ketut Lasmi, published in 2017. The distribution of analyzed diagrams in this book can be seen in the following table. Based on the data analysis results listed in the table above, the dominating diagram category in this textbook is the glossary of images with a percentage of 50% and a total frequency of 4 out of the total 4 diagrams in this textbook. This means that all diagrams in this textbook, besides belonging to other categories, also fall under the glossary of images category. Furthermore, another dominating diagram category in this textbook is the graph/histogram with a percentage of 38% and a frequency of 3 out of the total 4 diagrams in this textbook. The smallest percentage is given by the styled image diagram category at 12% with a frequency of 1. For other diagram categories such as photo, naturalistic image, scale diagram, flowchart-cycle, flowchart-stage, cross-section, map, table, and hybrid, they are not found in the material on Kinetic Gas Theory in this textbook, so their percentage is 0% with a frequency of 0.

The last book analyzed by the author is published by Mediatama, written by Nor Shalina Saputri and Rahmat Riyadi, published in 2021. This book is the most recently published book analyzed by the author. The distribution of analyzed diagrams in this book can be seen in the following table. Based on the analysis results shown in the table above, it can be concluded that the dominating diagram category in that textbook is the glossary of images with a percentage of 43%, consisting of 19 instances out of the total 24 diagrams in the book. Another dominating category is photos with a percentage of 23% and a frequency of 10. For the naturalistic image and graph/histogram categories, they each have the same percentage of 11%, with a frequency of 5 each. The styled image category has a percentage of 9%, with a frequency of 4 out of the total diagrams in the book. The scale diagram category contributes 2% with a frequency of 1. As for other categories such as flowchart-cycle, flowchart-stage, cross-section, map, table, and hybrid, they are not present in the material on Kinetic Gas Theory in this book, resulting in a percentage of 0% for each category with a frequency of 0.

Based on the analysis of the six physics textbooks for grade 11 on the topic of Kinetic Gas Theory, the largest diagram category in each book is the glossary of images. This demonstrates the necessity of captions or labels on diagrams in the Kinetic Gas Theory material. Since there are quite a few diagrams in this material with detailed features of different subjects, a glossary of images is required for each diagram to make each object in the diagram easily understood by the reader. On the other hand, categories like flowchart-cycle, flowchart-stage, map, and hybrid have a percentage of 0% in each book. This proves that these types of diagrams are not suitable for representing the content of Kinetic Gas Theory.

5. Discussion

This research aims to determine the distribution of diagrams and trends in the use of diagrams in high school physics textbooks, specifically in the kinetic gas theory material, with a descriptive quantitative research design. In this study, the largest distribution of diagrams is found in the glossary image category, accounting for a total percentage of 45% across the six analyzed books. Among the six books analyzed in this research, the glossary image is the category with the highest percentage in each book. This result differs from the research conducted by Slough (2010), where, based on his study on Grade 4 science textbooks, the photo category was the largest with a distribution percentage of 46.7%.

The disparity in research results between the current study and previous research can be attributed to the researcher's focus on analyzing diagrams in the Kinetic Gas Theory material in high school physics textbooks, which requires representations such as glossary images, naturalistic images, and stylized images. These types of diagrams are capable of representing each visualized object in detail. Slough (2010), in contrast, analyzed diagrams in science textbooks more broadly across various topics. His research revealed varying distribution representations for each topic. In physics, the frequency of photo diagrams was the second lowest (43.2%), and hybrid representations were the largest (20.9%). In the photo category, his findings align with the current research, indicating that the photo category has a relatively low distribution (11%).

In high school physics textbooks covering the Kinetic Gas Theory material, the hybrid category has a percentage of 0%. This is because in the Kinetic Gas Theory material, there is no need for a combination of graphs as the concepts do not require such representation. This differs from Slough's (2010) findings, as he reported a significant representation of hybrid diagrams in science textbooks. The distinction arises from the researcher's exclusive focus on the Kinetic Gas Theory material, where the concepts do not necessitate the representation of hybrid diagrams.

In the context of naturalistic image and photo categories, they tend to show a larger percentage than stylized images and graphs. This is because the Kinetic Gas Theory material, like physics material in general, is suitable for representation with naturalistic images capable of visualizing difficult-to-observe and challenging-to-describe objects. For the graph category, not all physics material is suitable for representation using graphs. These results align with Liu and Treagust's research, where the photo and naturalistic image categories had a higher percentage than stylized images and graphs (Muspratt and Freebody 2013; Liu and Treagust 2013).

The similarities between Liu and Treagust's (2013) findings and the results obtained in this textbook analysis support the researcher's opinion that the naturalistic image category is highly suitable for use in physics subjects. This category effectively portrays concepts with clarity and detail. Similarly, stylized images, which can outline concepts broadly in diagrams, are suitable and commonly used in science textbooks, especially in the Kinetic Gas Theory material analyzed by the researcher. However, the graph category tends to have a consistently lower percentage because graphs only depict specific quantitative information. In contrast, photos, naturalistic images, and stylized images can represent both general and specific information about a concept in the material.

6. Conclusion

Conclusion derived from the analysis of diagrams in the Kinetic Gas Theory material in high school physics textbooks. Overall, out of a total of 101 diagrams from the six books analyzed, the glossary image category has the highest frequency, totaling 74 with the largest percentage of 45%. In the second position, the naturalistic image and stylized image categories have frequencies of 23 each, with a percentage of 14%. In the third position, the photo and graph/histogram categories have frequencies of 18 each, with a percentage of 11%. In the fourth position, the table category has a frequency of 4 with a percentage of 3%. In the fifth position, the diagram scale category has a frequency of 3 with a percentage of 2%. The least frequent categories are flowing diagram, step flow diagram, cross-section/slice, map, and hybrid, each with a frequency of 0 and a percentage of 0%. Trends in the use of each diagram category in the Kinetic Gas Theory material in high school physics textbooks analyzed by the researcher, for the photo, naturalistic image, stylized image, glossary image, diagram scale, table, and graph/histogram categories, tend to be fluctuating from year to year. Whereas, for the flow diagram, step flow diagram, map, and hybrid categories, there is a 0% trend in usage in each textbook analyzed by the researcher.

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