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The Silent Architecture of Science Learning: A Critical Analysis of Visual Representations in Indonesian Integrated STEM Textbooks

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Abstract

This study aimed to analyze visual content on Indonesian junior high school science textbooks by discovering characteristics and patterns of STEM-related content. Textbooks could be a great vehicle to promote the interlinked importance of science, technology, engineering, and mathematics disciplines in a compact context. Therefore, analyzing the visual patterns and characteristics in the science textbook is paramount. The samples in this current study consisted of science textbooks from grade IX, specifically two of the most widely used science textbooks in Indonesia. The type, function, and pattern of the STEM-related contents were the main focuses. The results showed significant differences in the type, function, and pattern of STEM-related content in the selected textbook. Moreover, this current study reveals a poor, unequal representation of the type, function, and pattern of STEM-related content in the textbook. This empirical evidence, in the form of visualizing patterns and characteristics, is crucial, primarily to guide science teachers to utilize science textbooks in their everyday school life. Other essential implications are also discussed in this study, primarily pertaining to publishers, academia, and educational policymakers in Indonesia and other countries worldwide.

Keywords: Visual Content, Science Learning, Science Textbook, STEM Education

INTRODUCTION

A textbook is an essential part of the science learning process at the secondary school level in Indonesia. Textbooks can help students study science (biology) and make it easier to understand. Textbooks also contain not only writing or text but also illustrations or visualizations that describe a concept or things related to biology, aiming to avoid verbalism in students or readers. Moreover, textbooks are more than just carriers of information; they are the primary visual environment where students construct mental models of complex phenomena. According to Mayer's Cognitive Theory of Multimedia Learning (Mayer, 2014), students learn more deeply from words and pictures than from words alone. However, not all visuals are created equal. In an integrated STEM (Science, Technology, Engineering, and Mathematics) context, visuals must act as 'epistemic tools', images that don't just show a thing, but explain a process or a relationship. Therefore, the position of visualization of the textbook is vital and helps students generate a better understanding (Guo et al., 2018). Additionally, a well-presented visualization in a textbook can enhance the quality of the learning process (Jian & Ko, 2017). However, the visualization in the textbook must represent the concept and also need to follow the students' physical and mental development process (Cheung & Winterbottom, 2023). In addition, the visual content in textbooks must also accommodate the advancement of science and technology (Kang & Kim, 2023; Parthasarathy & Premalatha, 2022).

The development of science and technology, encompassed in STEM (Science, Technology, Engineering, and Mathematics) education, has occurred rapidly in various parts of the world and across disciplines, particularly over the last two decades. Many countries worldwide, including in Asia, such as Taiwan, Korea, Thailand, Vietnam, and Malaysia, have performed STEM education in a formal part of their education system (Wahono et al., 2025). It is undeniable that STEM education has great potential in successfully preparing human resources in the 21st century. Whereas in Indonesia itself, STEM education is still at the "initiation" stage (Wahono et al., 2023). Indeed, However, limited research in Indonesia has assessed how science textbooks contain information related to STEM education, especially visual content.

Furthermore, in developing visualizations in textbooks, a well-knowledge and strategies are needed. Therefore, the developed textbook could increase reader understanding (Roberts et al., 2015; Schoenherr et al., 2024). In addition, it should also be understood that visual literacy is not a skill that is generally possessed by everyone but will significantly depend on the clarity, format, and content of the visualization (Guo et al., 2018). Visualization will be effective if the reader already knows about the image obtained either in the field of science itself or the concept that is being studied (Cook, 2006). Thus, it is also necessary to understand the types of visual features that students often encounter in their science textbooks. Frequently, the visualization given in the textbook becomes a very complex picture that can confuse the students. Therefore, it is crucial to understand the existing information regarding the visual attributes, including the type, function, and even the pattern, in the Indonesian science textbooks.

The visual complexity of problems in visualizing concepts must be overcome hence that the students can quickly learn and understand. Furthermore, the visualization will become an entity that becomes the basis of students' minds in thinking or imagining a particular topic, which will later become a concept that will exist in the minds of the students. Therefore, an appropriate visualization is needed to match expectations, and in the end, it does not burden students in the interpretation process. The importance of visualization in science textbooks is also something that has great potential, especially as an effort to develop and improve the students understanding in science lessons and even better scientific literacy. In addition, knowledge of STEM-related visual content in science textbooks at the secondary school level will be significant information for teachers, other researchers, writers, publishers, and the government to prepare learning resources as time goes by the world development.

Research questions:

1. What are the types and functions of visuals and the visualization patterns related to STEM content in science textbooks at junior high schools' level in Indonesia?
2. Are there differences in the types, functions, and visualization patterns related to STEM content based on the topics in science textbooks at junior high schools' level in Indonesia?

Textbooks Visualization

Visualization originally came from things related to art, but now visualization plays a vital role in various fields, including education, cognitive psychology, literacy, and even new ones today in STEM (Science, Technology, Engineering, Mathematics) education (Baker, 2012). Therefore, the visualization in a textbook is no longer a complement to the book but a tool in understanding a scientific concept. Visualization can also be helpful for increasing memory capacity and improving the quality of learning (Norman, 2012).

The visualization function in textbooks is divided into five types (Guo et al., 2018; Sadoski & Paivio, 2013), namely: 1) decorative, serves as an ornament but does not support the text meaningfully. For example, a photo of a tiger in a Biology lesson; 2) representation, addressing aspects of its literal meaning and showing something concrete in an abstract concept; 3) organization, it is indispensable for student textbooks to help students remember organized information; 4) interpretation, part of the elements of representation and organization by presenting information in a way that can help the reader's understanding. For example, a map of Indonesia accompanied by the movements of the freedom fighters; 5) transformational, trying to change from an abstract thing into a form that can be remembered; for example, the positive and negative poles are marked with "+" and "–" to facilitate the explanation process.

The results of the study show that the right visualization of textbooks quantitatively shows a positive trend towards increasing students' understanding (Guo et al., 2018). Other studies have also shown that the inclusion of visualization in textbooks has a positive effect on students' reading comprehension (Guo et al., 2020). Therefore, it is necessary to carry out an in-depth analysis of visualization in biology science textbooks at the secondary school level, both in terms of the type, function and content of STEM. It is hoped that comprehensive information will be found on existing patterns and also on how to visualize textbooks that should be used in the 21st century.

STEM Education and Visualization

Recently STEM (science, technology, engineering, mathematics) education has been developing very rapidly in all parts of the world. In terms of definition, there is no fixed consensus in the literature. However, STEM education can be formed of teaching and learning in a particular STEM class (Bybee, 2013; Wahono et al., 2023). Another study argues that STEM education is a teaching approach that integrates at least two of the four STEM domains in an integrated way (Baran et al., 2016; Bybee, 2013). Meanwhile, other studies mention that STEM education could be a teaching and learning that emphasizes hands-on and problem-solving activities by using some disciplines and skills (Martín-Páez et al., 2019; Wahono et al., 2020; Wahono et al., 2025). Therefore, in this current study context, the STEM textbook and STEM-related content refer to any textbooks as a learning resource in a particular STEM domain (e.g., science).

Many researchers have proved the benefits of STEM education enactment in the classroom. One of the promising benefits is its potential to hone students' opinions and decision-making skills (Wahono et al., 2023; Wahono et al., 2025). STEM education positively affects the development of students' thinking processes because it involves not only one disciplinary perspective (Martín-Páez et al., 2019). Students are accustomed to convergent and divergent thinking in learning conditions that have been set through STEM education. Therefore, it is undeniable that STEM education plays a significant role in attracting students' interest in learning and, in the end, improving student learning outcomes. STEM education can also be a powerful tool in assisting the complicated decision-making process for students. However, limited study has been found that analyzes the visual content of biological science textbooks concerning STEM-related education content.

Visualization plays a crucial role in STEM education, as it helps students better understand the world around them and draw conclusions from complex data (Calcetero, 2021; Teplá et al., 2022). Incorporating visualization into science textbooks and classroom activities potentially enhance students' ability to analyze experimental data, communicate findings, and develop critical thinking skills (Wilkerson et al., 2025; Yoon et al., 2021). Some benefits of visualization in STEM education include: First, visual representations can help students grasp abstract concepts and principles more effectively than text alone (Evagorou et al., 2015). Second, data visualization techniques can facilitate the analysis of experimental data and reveal patterns or trends that may not be apparent from raw data. Third, effective visualization skills are essential for students to communicate their findings and insights to others, making it a vital component of scientific inquiry and collaboration. Fourth, visualizations can engage students and make the learning process more enjoyable, as they allow students to explore data and discover insights for themselves (Guo et al., 2018). Therefore, to fully realize the potential of visualization in STEM education, it is essential to integrate it into the curriculum and provide students with the necessary tools and resources to create and interpret visual representations (Calcetero, 2021). By incorporating visualization into science textbooks and classroom activities, educators can foster a deeper understanding of STEM concepts and promote critical thinking and problem-solving skills among students.

The Cognitive Role of Visuals in STEM

The fundamental premise of this study is anchored in Mayer's Cognitive Theory of Multimedia Learning (CTML), which posits that the human brain processes information through two distinct channels: one for verbal input and one for pictorial representation. This dual-channel architecture suggests that meaningful learning occurs not through the passive absorption of facts, but through the active processing of integrating these two streams into a coherent mental model. In the context of STEM education, where concepts are often abstract or multi-dimensional (Adanur-Sönmez et al., 2025; Vermehren et al., 2025; Wahono et al., 2025), visuals serve as essential scaffolding (Zhang & Jia, 2024). However, CTML warns of the Limited Capacity of working memory. If a textbook is saturated with visuals that do not directly support the instructional objective, it creates "extraneous cognitive load" that hinders the student's ability to select and organize relevant information. Therefore, analyzing whether a visual is "decorative" or "interpretative" is not merely a matter of categorization, but an evaluation of the textbook's cognitive efficiency in facilitating knowledge construction.

Furthermore, the Coherence Principle within CTML provides a critical lens for examining the "unequal distribution" of visual types found in this study. This principle suggests that learning is significantly improved when extraneous or decorative material is excluded rather than included (Mayer, 2024). When Indonesian science textbooks rely heavily on representational photos that lack interpretative depth, they risk distracting the learner from the core STEM epistemologies, such as mathematical modeling or engineering design that require more structured, transformational visuals like schematics and flowcharts (Ghritlahare, 2025). By moving beyond a simple count of images and examining their pedagogical function, this study interrogates how the current visual design of science textbooks either supports or subverts the "Integrated STEM" approach. Without a balanced distribution of visual attributes that include the "M" (Mathematics) and "E" (Engineering) components, the textbook fails to provide the necessary visual language for students to transition from surface-level recognition to deep, cross-disciplinary understanding.

METHOD

Research Type

This current research used a content analysis study. Indeed, the content analysis performed in this study was focused on counting and measuring of the visual (quantitative). We made inferences about the producers and audience of the texts that we analyzed.

Therefore, this study aimed to analyze the types, functions, and patterns of STEM-related content of visuals in secondary school science textbooks in Indonesia.

This study focused on visuals in two science textbooks based on the revised K-13 curriculum (the last version of the Indonesian curriculum), particularly in grade IX, Junior High School. In selecting textbooks, we identified those adopted by highly populated students, and they are "Market Leaders" which cover >70% of the student population in Indonesia, so they are functionally representative even though the numbers are small. The term 'textbook' refers to a book that is widely used as a primary resource by students in daily science learning at school and is readily available in the market. The textbooks can be accessed in both printed and online forms (Yukaliana, 2018; Zubaidah et al., 2018).

Furthermore, in this method, what is meant by visual as a graphical display is not only limited to diagrams, maps, graphs, and tables, but also a visual may contain some text, such as a label on a regional map or other related information. Still, the primary source of information is from visual presentations, not textual ones. The topics were selected randomly from several topics in the two science textbooks from different publishers. In total, we have selected six topics that comprised of the human reproduction system (HRS), plant & animal breeding system, heredity of living things (HLT), biotechnology (Biotech), land & survival of life (LSL), and green technology (GT).

Coding Scheme

This study adopted a comparative approach as an analytical tool (Coleman & Dantzler, 2016; Fingeret, 2012; Guo et al., 2018). Then, we also adapted Fingeret's coding scheme to generate a detailed list of subtypes (see Table 1). For example, we identify a chart as a visual that shows the components of an entire static relationship with labeled sections. Furthermore, our research team independently developed a tentative definition for each visual category and found representative examples as part of this research.

Table 1. The Framework Analysis of Visual Content

Variables	Sub variables	Descriptions
Type of Visual	Photo	An image created by light falling on a photosensitive surface, usually photographic film or an electronic image sensor
	Chart	A graphical representation for data visualization, in which "symbols represent the data, such as bars in a bar chart, lines in a line chart, or slices in a pie chart
	Diagram	A symbolic representation of information using visualization techniques
	Visual Text	A text in which the image plays a major role in the audiences' response

Variables	Sub variables	Descriptions
	Schematic	A representation of the elements of a system using abstract, graphic symbols rather than realistic pictures
	Flowchart	A type of diagram that represents a workflow or process
Function of Visual	Decorative	Ornament but does not support text meaningfully
	Representation	Addressing aspects of its literal meaning and showing something concrete in an abstract concept
	Organization	Organized/structured information
	Interpretation	Part of the elements of representation and organization by presenting information in a way that helps readers understand
	Transformation	Strive to change from an abstract thing to a memorable form
	Extensional	Represent textual information and add new information
STEM-Related Content	Science	The study of natural phenomena involving observation and measurement
	Technology	Innovations to modify nature to meet human needs and desires
	Engineering	Knowledge and skills to design and construct machines, tools, systems, materials and processes that are useful to humans
	Mathematics	Knowledge of patterns and relationships, both in the form of numbers/counts and non-numbers/counts
	Others	Other things outside of science, technology, engineering, mathematics

We also developed a coding scheme to illustrate the functionality visually. However, we coded visuals based on the main functions of visualization, namely, decorative, representation, organization, interpretation, and transformation. However, later, when we found a visual with several different functions (for example, a simple diagram can be a representation and organization), we coded the most prominent function, which would be determined or seen from the surrounding text. In addition to the five main functions above, Fingeret (2012) encodes visual functions that add new information as extensional, even if the main function was a representation (for instance). We would identify a visual with an extensional connection when it both represents textual information and adds new information. When reading such visuals, students would be able to easily interpret and relate additional information to what they have read in the text.

Data Analysis

To deal with the first research question, which is what the types, functions, and visualization patterns related to STEM content in science textbooks are, we performed a qualitative analysis using the IBM SPSS Statistics for Windows software (Version 25). Then, to answer the second research question, namely, are there differences in the types, functions, and visualization patterns related to STEM content based on topics in the science textbook, we performed a likelihood-ratio chi-square statistic (G2) with the same software, which aims to check whether the visuals in the biology science textbooks are statistically significant. Indeed, the G2 is based on the ratio of the observed to the expected frequencies. Moreover, an advantage of the likelihood ratio chi-square is that G2 for a large dimensional table can be neatly decomposed into smaller components, and this case cannot be done precisely with Pearson's chi-square (Howell, 2011).

RESULTS AND DISCUSSION

Efforts to develop and increase the understanding of readers/students in Biology science lessons and even scientific literacy, in general, can be done by maximizing visual functions and roles. On the other hand, textbooks are the primary reference for high school students' biology knowledge in Indonesia. Thus, this study aims to investigate existing conditions regarding types, functions, and visual patterns related to STEM content and to reveal the basic differences in these conditions based on the topic of material in Biology textbooks.

Visual Types and Functions and Visualization Patterns Associated with STEM Content

The types and functions of visuals and visualization patterns related to STEM content in science textbooks at the junior high school level in Indonesia can be seen in Figures 1 and 2. These figures reflect the existing condition of science textbooks in Indonesia regarding the content, especially the embedded visual that the students see during their learning. Notably, the visual type of the science textbook is clearly categorized in Figure 1.

Figure 1 reveals much unique information from the visual types of Indonesian junior high school science textbooks. First, the leading type of visual in the textbook is the photo. This type of visual almost dominates all the other types, namely 69,54% of the total of 174 pictures in the selected topics in the textbook. This condition is quite similar to the study conducted by Guo et al. (2018). They found that photographs and general images are the most common visuals in the upper elementary grades because at these grades, science and social studies textbooks (62.4% and 16.3%, respectively). Meanwhile, in order to leverage the student analysis skills and higher-order thinking skills (HOTS), we need more visualization on the types of charts, diagrams, and flowcharts.

However, the findings of this study reveals that the visual type of chart, diagram, and flowchart has the lowest position from the bottom. Even, we could not find any chart type (0%) of all the visuals in the selected junior high school science textbooks. Based on the aspects of the PISA scientific literacy assessment framework (OECD, 2017), the student needs an ability to interpret data and evidence scientifically. Then, we argue that in terms of a textbook as a learning resource, the visual chart and diagram are crucial. Moreover, based on the proposed focus domain for PISA 2022 creative thinking assessment (OECD, 2021), the visual and written will be an item belonging to the creative expression domain. Therefore, it is urgent to consider the proportion of this visual type in each science textbook in Indonesia or even in the rest of the world. Then, many parties such as publishers, teachers, researchers, and educational policymakers should be aware of the visual content equalization in science textbooks and textbooks in general.

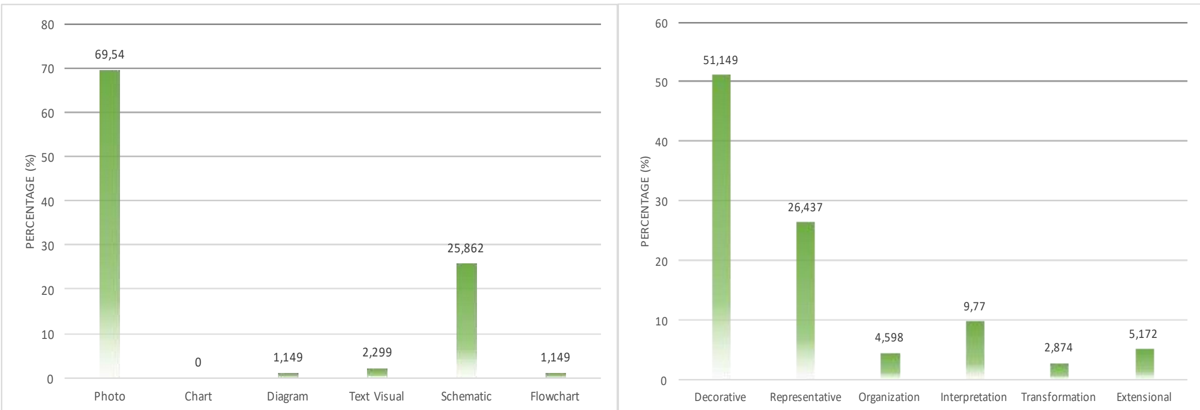

Figure 1. Visual Types (Left) and Function (Right) of the Indonesian Junior High School Science Textbooks

The Figure of the function variable (right) in Figure 1 is also slightly the same as the previous figure, which has much important information regarding the visual function in the Indonesian junior high school science textbooks. The decorative is in the top position, shown in the figure. It has more than half of the total visual function found in the science textbook. The decorative visual in this term means that the visual seems like an ornament, and it does not support the text meaningfully. One example we provide in this function is the figure of the orange tree. The text discusses the land and soil; however, the picture (orange's tree) does not clearly relate to the text, and there is not enough information regarding its relationship. The visual functions only as an ornament that makes it more aesthetically attractive.

More important things were also revealed from this study. The unequal distribution function of visuals from the science textbook is shown in Figure 1. Even though the interpretation function is essential for students, the interpretation percentage is no more than 10% in this study. Meanwhile, many well-developed textbooks should comprise the interpretation function on the top two ranked distributions from the total function (Guo et al., 2018). Moreover, some previous studies indicated that the most advantageous visual would be interpretational and transformational, as they would help the reader encode content in concrete and novel ways (Carney & Levin, 2002). The interpretation is a part of the elements of representation and organization by presenting information in a way that helps readers understand (Binali et al., 2024; Zerman & Pektas, 2023). The interpretation is one key element in the PISA framework to hone students' scientific literacy (Wu, 2025). In addition, this current study result shows the organization's function is also a tiny percentage. However, Myers et al. (2002) argue that social studies textbooks were more likely to contain organizational or interpretational visuals. These form and function outcomes are connected because tables and maps generally add to information organization.

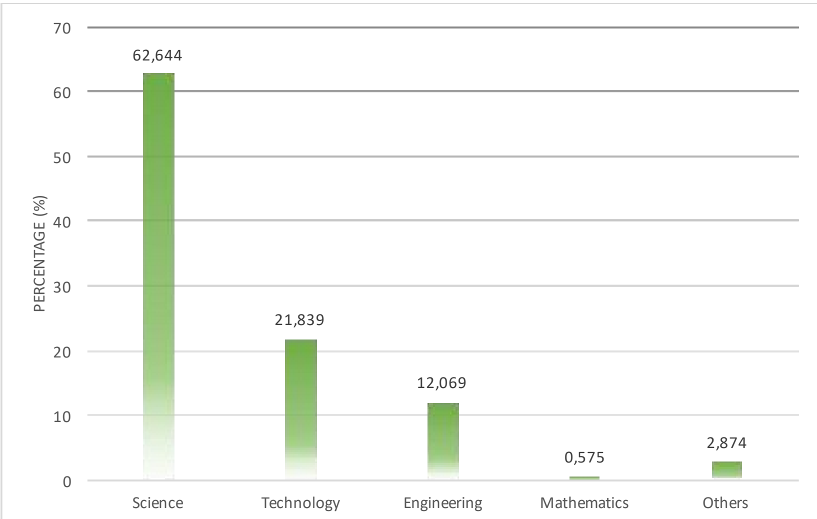

Figure 2. Patterns of Visualization Related to the STEM Content of Indonesian Junior High School Science Textbooks

Figure 2 shows that more than 60% of the STEM visual content is science. The provided data is plausible because it is a science textbook. However, the opposite condition shows that mathematics is the smallest portion of the visual percentage (.575%). Then, in order from the highest to the lowest, they are science, technology, engineering, others, and mathematics. An example of the visual science content, in this case, is DNA and RNA molecules. Meanwhile, the visual mathematics content instance is about the picture that shows a number of fish divided into several groups (1, ½, 1/3 portion). Furthermore, the "others" comprise many things outside of science, technology, engineering, and mathematics. A picture of kids playing football in the field was an instance of the "others" visual content in this current study.

Based on the findings in Figure 2, reveal a 'STEM silo' within the visuals. While Science (S) is vibrantly represented, Mathematics (M) remains virtually invisible in the visual landscape. This absence is not just a numerical deficit; it is a pedagogical one (Wahono et al., 2025). Without 'M', the language of data visuals remains at the level of 'looking at' rather than 'thinking with.' The heavy reliance on "decorative photos" suggests that textbooks are being designed for engagement rather than deep cognitive inquiry. This condition creates a 'glass ceiling' for students. They see the products of science (the photos), but they cannot see the underlying logic (the charts and schematics).

Differences in Types, Functions, and Visualization Patterns Related to STEM Content Based on the Topics

The topic is one of the crucial things in terms of learning resources. Topics guide teachers to prepare an appropriate teaching method that matches the topics' characteristics. Moreover, a learning topic should contain well-crafted content, including visualizations, and should be distributed equally and for a purpose among them. Therefore, the second research question aims to determine whether or not there are differences in the types, functions, and visualization patterns related to STEM content based on the topics in science textbooks at the junior high school level in Indonesia.

We found some interesting findings based on the current study data (Table 2). First, there was no "chart" type of visual on all of the topics. Second, the type of visual on most topics is "photos". Third, the "photo & schematic" is available on all the topics. Fourth, the "flowchart" is only available on the "HRS and biotech" in a small portion. However, even though the result reveals some common patterns, it also shows several unique variations. Therefore, we need an advanced statistical analysis to know whether there are significant differences in types, functions, and visualization patterns related to STEM content based on the topics. Table 2 shows the detailed information to understand the second research question.

Table 2. Types, Functions, and Visualization Patterns Related to STEM Content Based on the Topics in Science Textbooks

Variable	Pattern of Topics	Count (N=174)	Likelihood-Ratio Chi-Square (G^2)	Asymptomatic Significance (2-sided)
Types of Visual	HRS*PHT_CRT_DGR_TVL_SCM_FLC; PABS*PHT_CRT_DGR_TVL_SCM_FLC; HLT*PHT_CRT_DGR_TVL_SCM_FLC; Biotech*PHT_CRT_DGR_TVL_SCM_FLC;	8_0_0_0_11_1; 37_0_0_0_11_0; 13_0_1_3_5_0; 23_0_0_1_4_1;	34.892	.021

	LSL*PHT_CRT_DGR_TVL_SCM_FLC; GT*PHT_CRT_DGR_TVL_SCM_FLC;	19_0_1_0_4_0; 21_0_0_0_10_0;		
Function of Visual	HRS*DCR_RPR_ORG_ITP_TRF_EXT PABS*DCR_RPR_ORG_ITP_TRF_EXT HLT*DCR_RPR_ORG_ITP_TRF_EXT Biotech*DCR_RPR_ORG_ITP_TRF_EXT LSL*DCR_RPR_ORG_ITP_TRF_EXT GT*DCR_RPR_ORG_ITP_TRF_EXT	2_7_3_5_0_3; 32_5_2_7_0_2; 11_6_1_0_4_0; 15_9_0_3_0_2: 11_11_2_0_0_0; 18_8_0_2_1_2;	67.300	<.001
STEM-Related	HRS*S_T_E_M_O PABS*S_T_E_M_O HLT*S_T_E_M_O Biotech*S_T_E_M_O LSL S_T_E_M_O GT*S_T_E_M_O	19_1_0_0_0; 42_5_0_1_0; 21_1_0_0_0; 12_14_3_0_0; 8_2_11_0_3; 6_16_7_0_2;	111.630	<.001

Note: HRS = Human Reproduction System; PABS = Plant & Animal Breeding System; HLT = Heredity of Living Things; Biotech = Biotechnology; LSL = Land & Survival of Life; GT = Green Technology; PHT = Photo; CRT = Chart; DGR = Diagram; TVL = Text Visual; SCM = Schematic; FLC = Flowchart; DCR = Decorative; RPR = Representative; ORG = Organization; ITP = Interpretative; TRF = Transformative; EXT = Extensional; S = Science; T = Technology; E = Engineering; M = Mathematics; O = Others.

Table 2 reveals a significant statistical difference of the visual types in the science textbook based on topics. The likelihood-ratio chi-square score is 34.892, with a significance score of .021. It literally means that those topics have different patterns according to their type of visual in the Indonesian science textbook. Moreover, even though the "photo" type dominates the count, they have differed in terms of quantities and the pattern. Some topics, for instance, the plant & animal breeding system, the type of photograph was most prevalent, meanwhile, another topic (human reproduction system), the schematic type was dominant.

The visual function variable also shows a slightly similar result (Table 2). A significant statistical difference appears in the visual function in the science textbook based on the topics. The likelihood-ratio chi-square score is 67.300 with a significance score of <.001. It means that those topics have different patterns according to visual function in the Indonesian science textbook. Indeed, the decorative function appears as the typical pattern on most topics, except in the topic of the human reproductive system, which is distributed nearly equally across all topics.

The data also shows a significant difference among the topics in terms of STEM-related content. The likelihood-ratio chi-square score is 111.630 with a significance score of <.001. It means that those topics have different patterns according to the visual STEM-related content in the science textbook. Some interesting findings are shown in this data. First, the science-related group dominates in terms of quantity in this variable. Second, even though this is a science textbook, some particular topics tend to comprise a majority of, for instance, the technology content in the biotechnology topic and the engineering on the land and survival of life topic.

The influence of the topics is strong in determining the distribution of STEM-related content. Guo et al. (2018) conducted a study, and they argued that the types of visuals significantly differed between the topics and disciplines. Each topic has a unique pattern, with dominant STEM-related content. Behnke (2021) argued that comprehensibility (image content connects to the topic) is one of the usability qualities of visual design elements in textbooks that may affect learning motivation and knowledge construction. However, one should discuss the fact that the mathematical content is scarce in appearing as a visual of STEM-related content. Meanwhile, this mathematical literacy and content are needed for students, even in science textbooks, especially when they solve a PISA test (OECD, 2017; OECD, 2021). Finally, the weakness of textbooks would lead to a shortcoming of the teachers in teaching and learning preparation. Moreover, teachers' lack of preparation or attention to visual literacy is specific in Indonesia, but it is also documented in the United States, South Africa, and Norway (Erstad, 2012; Moodley, 2013).

CONCLUSION

This current study reveals much unique information about the visual types and functions of Indonesian junior high school science textbooks. Some visual types (e.g., photograph) and functions (e.g., decorative) are extremely dominant over others. Meanwhile, the other visual functions (e.g., interpretation) are available in tiny portions or are not available at all for the chart visual type. Moreover, this research also shows a significant statistical distribution of visual types, functions, and the pattern of STEM-related content on the Indonesian Science Textbook. Based on the result analysis and discussion from literature, the shortcomings of the visual pattern of type, function, and STEM-related content could potentially promote the weakness of Indonesian students' skills and literacy on solving science student performance metrics (e.g., PISA test). While it is tempting to link these visual imbalances directly to student performance metrics, the more immediate concern is the misalignment between Indonesia's 21st-century educational goals and the instructional tools provided to achieve them. To truly transition into an 'Initiation' stage of STEM, Indonesian textbooks must evolve. They need to shift from being 'picture books' of science to becoming 'manuals for inquiry' where visuals, text, and data are inextricably linked.

However, this research faced several limitations. For instance, this study only selected two of the most prominent publishers in Indonesia. Therefore, it is necessary to compare the results by conducting and adding more publishers. Nevertheless, we firmly believe that this current result could represent the actual condition of visualization science textbooks in Indonesia. This result may also be the basis for further studies, such as investigating qualitative and quantitative approaches of the best visual content ratio in a science textbook. Therefore, this current study has many crucial impacts for several parties, such as publishers, academia (teachers and researchers), and educational policymakers in Indonesia or other countries throughout the world.

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REFERENCES

Adanur-Sönmez, E., Aydın-Ceran, S., & Koçak, N. (2025). Student experiences in context-based stem instructional design: An investigation focused on scientific creativity and interest in STEM career. *Education Sciences, 15*(9), 1218. https://doi.org/10.3390/educsci15091218

Baker, F. W. (2012). *Media literacy in the K–12 classroom*. Washington, DC: International Society for Technology in Education.

Baran, E., Bilici, S. C., Mesutoglu, C., & Ocak, C. (2016). Moving STEM beyond schools: Students'perceptions about an out-of-school STEM education program. *International Journal of Education in Mathematics Science and Technology, 4*(1), 9–19. https://doi.org/10.18404/ijemst.71338

Behnke, Y. (2021). Usability qualities of 'well-designed'geography textbook visuals. *Journal of Visual Literacy*, *40*(1), 15-33. https://doi.org/10.1080/1051144X.2021.1902042

Binali, T., Chang, C.-H., Chang, Y.J., & Chang, H.-Y. (2024). High school and college students' graph-interpretation competence in scientific and daily contexts of data visualization. *Science & Education*, 33, 763-785. https://doi.org/10.1007/s11191-022-00406-3

Bybee, R. W. (2013). *The case for STEM education: Challenges and opportunities*. NSTA press.

Calcetero, M.A. (2021). *Teaching Data Visualization to STEM Students*. Robotlab. Accessed at https://www.robotlab.com/blog/teaching-data-visualization-to-stem-students on November 10, 2023.

Carney, R. N., & Levin, J. R. (2002). Pictorial illustrations still improve students' learning from text. *Educational Psychology Review, 14*, 5–26. https://doi.org/10.1023/A:1013176309260

Cheung, K. K. C., & Winterbottom, M. (2023). Students' integration of textbook representations into their understanding of photomicrographs: Epistemic network analysis. *Research in Science & Technological Education, 41*(2), 544-563. https://doi.org/10.1080/02635143.2021.1920382

Coleman, J. M., & Dantzler, J. A. (2016). The frequency and type of graphical representations in science trade books for children. *Journal of Visual Literacy, 35*, 24–41. https://doi.org/10.1080/1051144X.2016.1198543

Cook, M. P. (2006). Visual representations in science education: The influence of prior knowledge and cognitive load theory on instructional design principles. *Science Education, 90*(6), 1073-1091. https://doi.org/10.1002/sce.20164

Erstad, O. (2012). The learning lives of digital youth-Beyond the formal and informal. *Oxford Review of Education, 38*, 25–43. https://doi.org/10.1080/03054985.2011.577940

Evagorou, M., Erduran, S., & Mäntylä, T. (2015). The role of visual representations in scientific practices: from conceptual understanding and knowledge generation to 'seeing' how science works. *International Journal of STEM Education, 2*(11). https://doi.org/10.1186/s40594-015-0024-x

Fingeret, L. (2012). Visuals in children's informational texts: A content analysis (Unpublished doctoral dissertation). Michigan State University, East Lansing.

Ghritlahare, A. (2025). The Role of Flowcharts in Problem Solving and Process Visualization. https://doi.org/10.5281/zenodo.15358152.

Guo, D., Wright, K. L., & McTigue, E. M. (2018). A content analysis of visuals in elementary school textbooks. *Elementary School Journal, 119*(2), 244–269. https://doi.org/10.1086/700266

Guo, D., Zhang, S., McTigue, E., & Wright, K. L., (2020). Do you get the picture?: A metaanalysis of the effect of graphics on reading comprehension. *AERA Open, 6*(1). https://doi.org/10.1177/2332858420901696

Howell, D. C. (2011) Chi-Square Test: Analysis of Contingency Tables. In: Lovric M. (eds) *International Encyclopedia of Statistical Science*. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-04898-2_174

Jian, Y. C., & Ko, H. W. (2017). Influences of text difficulty and reading ability on learning illustrated science texts for children: An eye movement study. *Computers and Education, 113*, 263–279. https://doi.org/10.1016/j.compedu.2017.06.002

Kang, E., & Kim, H. S. (2023). Analysis of light-related visual images presented in elementary schools science textbooks in Kore, the United States, and Japan. *Asia-Pasific Science Education, 9*(2), 265-298. https://doi.org/10.1163/23641177-bja10068

Martín-Páez, T., Aguilera, D., Perales-Palacios, F. J., & Vílchez-González, J. M. (2019). What are we talking about when we talk about STEM education? A review of literature. *Science Education*, 1–24. https://doi.org/10.1002/sce.21522

Mayer, R. E. (2014). Cognitive theory of multimedia learning. In R. E. Mayer (Ed.), The Cambridge handbook of multimedia learning (2nd ed., pp. 43–71). Cambridge University Press. https://doi.org/10.1017/CBO9781139547369.005

Mayer, R. E. (2024). The Past, Present, and Future of the Cognitive Theory of Multimedia Learning. *Educational Psychology Review, 36*(8). https://doi.org/10.1007/s10648-023-09842-1

Moodley, V. (2013). In-service teacher education: Asking questions for higher order thinking in visual literacy. *South African Journal of Education, 33*(2), 1–17. https://hdl.handle.net/10520/EJC134989

Myers, C. B., Dougan, A. M., Barber, C. R., Dumas, W., Helmkamp, C. J., Lane, J. W., . . . Theisen, R. (2002). *National standards for social studies teachers* (Vol. 1). Silver Springs, MD: National Council for the Social Studies.

Norman, R. R. (2012). Reading the graphics: What is the relationship between graphical reading processes and student comprehension? *Reading and Writing, 25*(3), 739–774. https://doi.org/10.1007/s11145-011-9298-7

OECD. (2017). *PISA 2015 Assessment and Analytical Framework: Science, Reading, Mathematic, Financial Literacy and Collaborative Problem Solving, PISA*, OECD Publishing, Paris, https://doi.org/10.1787/9789264281820-en.

OECD. (2021). *PISA 2021 Creative Thinking Framework (third draft), Organization for Economic Co-Operation and Development*, https://www.oecd.org/pisa/publications/PISA-2021-Creative-Thinking-Framework.pdf.

Parthasarathy, J., & Premalatha, T. (2022). Content analysis of visual representations in biology textbooks across selected educational boards from Asia. *Cogent Education, 9*(1). https://doi.org/10.1080/2331186X.2022.2057002

Roberts, K. L., Norman, R. R., & Cocco, J. (2015). Relationship Between Graphical Device Comprehension and Overall Text Comprehension for Third-Grade Children. *Reading Psychology, 36*(5), 389–420. https://doi.org/10.1080/02702711.2013.865693

Sadoski, M., & Paivio, A. (2013). *Imagery and text: A dual coding theory of reading and writing*. New York: Routledge.

Schoenherr, J., Strohmaier, A. R., & Schukajlow, S. (2024). Learning with visualizations help: A meta-analysis of visualization interventions in mathematics education. *Educational Research Review, 45*. https://doi.org/10.1016/j.edurev.2024.100639

Teplá, M., Teplý, P., & Šmejkal, P. (2022). Infulence of 3D models and animations on students in natural subjects. *International Journal of STEM Education, 9*(65). https://doi.org/10.1186/s40594-022-00382-8

Vermehren, J. A. V., Trikoili, A., & Pittich, D. (2025). Abstract thought in STEM education: an integrative literature review. *International Journal of STEM Education, 12*(54). https://doi.org/10.1186/s40594-025-00573-z

Wahono, B., Lin, P. L., & Chang, C. Y. (2020). Evidence of STEM enactment effectiveness in Asian student learning outcomes. International Journal of STEM Education, 7(1), 1–18. https://doi.org/10.1186/s40594-020-00236-1

Wahono, B., Sholihah, I.M., Narulita, E. (2023). Visual Content Analysis of STEM-Related Content in Indonesian Vocational High Schools Biology Textbooks. Journal of Science Learning, 6(3), 281-293. https://doi.org/10.17509/jsl.v6i3.53772

Wahono, B., Purmanna, A., Ramadhani, R., & Manalu, M.S. (2025). Strengthens the Student Collaboration and Decision-making Skills through Integrated STEM Education: A Research and Development Study. *Science Education International, 36*(1),86-93. https://doi.org/10.33828/sei.v36.i1.9

Wilkerson, M. H., Kim, J., Lee, H. S., Stokes, D. J., & Ferrell, M. (2025). How teachers envision using data visualization discussion tasks in classroom instruction. *International Journal of Science and Mathematics Education, 23,* 2653-2687. https://doi.org/10.1007/s10763-024-10521-y

Wu, Y. (2025). Analyzing scientific literacy in asia's top five pisa 2022 performers using hierarchical linear modeling and bourdieu's theory of practice. *Asia-Pacific Science Education, 11*(1), 95-130. https://doi.org/10.1163/23641177-bja10091

Yukaliana, Y. (2018). *IPA Biologi [Biological Science]*. Jakarta: Erlangga.

Yoon, H.-G., Kim, M., & Lee E. A. (2021). Visual representation construction for collective reasoning in elementary science classrooms. *Education Sciences, 11*(5), 246. https://doi.org/10.3390/educsci11050246

Zerman, K. G., & Pektaş, M. (2023). Examination of visual items in secondary school science textbooks. *Journal of Social Sciences and Education*, 6, 264-278. https://doi.org/10.53047/josse.1353086

Zhang, C., & Jia, B. (2024). Enriching STEAM education with visual art: education benefits, teaching examples, and trends. *Discover Education, 3*(247). https://doi.org/10.1007/s44217-024-00354-w

Zubaidah, S., Mahanal, S., Yuliati., L., Dasna., I.W., Pamgestuti, A., Puspitasari, D.R., Mahfudhilah, H.T., Robitah, A., Kurniawati, Z.L., Rosyida, F., Sholihah, M. (2018). *Ilmu Pengetahuan Alam [Natural Science]*. Jakarta: Puskurbuk Kemdikbud RI.