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A Study on Effects of Multimodal Science Text Design on Meaning-Making of Science Content: Science Teachers' Perspectives

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Abstract. Numerous studies demonstrated that the meaning-making of scientific knowledge is affected by the design of multimodal science texts. Various modes are co-operated together in certain inter-semiotic mechanisms to produce meaning in multimodal texts. Based on this perspective, this research seeks to investigate the effect of mode level in science texts and compositional arrangement on the meaning-making of science concepts and processes. In this context, four science texts with the same content (transformation of energy) at different mode densities and two science texts with the same content (covalent bonding) one of which is arranged in accordance with variation theory of learning are designed. By using the case study method, this research explored six experienced science teachers' views about the effects of mode level and multimodal text composition on meaning-making. The data were collected with semi-structured interviews. The thematic analysis was employed for data analysis. The findings demonstrated that mode density may affect meaning-making and so learning since different modes have affordance to represent different meaning and meaning relationship types. Besides, multimodal text composition may foreground the critical aspects of content, and help to design a coherent multimodal science text.

Keywords: Multimodality, Meaning-Making, Pedagogic Texts, Learning, Science Teaching

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INTRODUCTION ~ Learning is accepted to involve intra-individual and inter-individual processes (Airey & Linder, 2009; Fredlund, 2015). Inter-individual account of learning deals with the mediating tools during the communication of scientific knowledge (Waldrip et al., 2010). Learning is seen as mediated action (Vygotsky, 1978) in which meaning is conveyed by various representations, such as language, visual imagery, mathematical symbolism, gestures, tools, and meaning-making, that is seen as internal representations shaped by various semiotic resources within a specific context (Jewitt, 2008). Accordingly, learning is re-contextualization and re-construction of meaning conveyed by the external resources such as pedagogic texts used in the classroom (Jewitt et al., 2001). As such, the texts that demonstrate scientific information and knowledge employ much importance in teaching and learning of science (Jaipal, 2010; Meneses et al., 2018). Furthermore, a discourse of science is multimodal in which various modes co-operate together to realize meaning by contextualizing the meaning deployed by each mode (Liu & Owyong, 2011; O'Halloran, 2007). However, the effects of multimodal texts and the density of modes (Norris, 2011) on meaning-making and learning still need to be studied. This research focuses on the multi-semiotic construction of scientific knowledge as part of meaning-making practices in the primary-level science classroom. In this context, this research aims at exploring the effect of text design strategies on the meaning-making of science concepts. The purpose of this research is to explore the views of experienced science teachers of primary-level gifted/talented students. It is hypothesized that these views may be part of the evaluation of the role of text design strategies on meaning-making.

Jewitt et al. (2001) investigate the roles of multimodal texts on the learning of science concepts and learning products designed by students. They demonstrate that the resources and pedagogic text design strategies employed by teachers play critical roles in meaning-making and understanding. Liu & Owyong (2011) explore the multimodal nature of the discourse of science and demonstrate how different modes and semiotic resources are combined to expand meaning by conceptualizing relationships between the modes. They claim that the symbolic and mathematical mode can reconstruct the daily life experience as scientific knowledge. This is valid for other instances about how scientific knowledge can be contextualized by using various modes and making the scientific knowledge more understandable. Oliveira et al. (2014) report that teaching science is a multimodal orchestration that involves the collaboration of various modes such as written and spoken language, images, and gestures. Patron et al. (2017) explore teachers' visual representational reasoning when they choose and design pedagogic science texts. The study claims that "if meaning-making is to take place in an appropriate, holistic, and meaningful way" the object of learning should involve three components, namely (1) "the disciplinary relevant aspects", (2) "insight into critical features that will potentially present challenges to the discernment of any of the disciplinary relevant aspects (or their parts)", and (3) "a semiotic approach that is built on dimensions of affordance and variation in ways that provide optimal possibilities for access to the needed discernment". These research are exemplary cases to demonstrate the communication of scientific knowledge and the role of learning resources in meaning-making and learning processes in science classroom.

THEORETICAL FRAMEWORK

This research is mainly informed by three theoretical lenses, namely social semiotic systemic functional theory (SFT)(Halliday, 2004) and multimodality (Jewitt et al., 2016), thematic pattern approach (Lemke, 1990), and variation theory of learning (VTL) (Marton & Tsui, 2004). Firstly, SFT is used to analyze and conceptualize meaning-making processes in science texts. According to SFT, meaning takes place as a result of choices from semiotic resource systems. The choices are paradigmatic and syntagmatic. The paradigmatic choices involve selecting semiotic resources, while the syntagmatic choices relate to sequencing or ways of combining of them. Semiotic resource systems allow options of choice to make meaning. In addition, SFT simultaneously look at instances of semiotic systems where choices have made in in the system. A text is a specific instance of these selections (Fredlund, 2015; Tang et al., 2011). SFT's metafunctional principle posits that semiotics resources used in the texts simultaneously realize ideational meaning (experiential meaning and logical relations), interpersonal meaning (the social enactment between producer and reader of the text), and textual meaning in which text is organized around the first two functionalities to be coherent in making meaning. This metafunctional principle provides "a basis for examining the functionalities of semiotic resources and for analyzing how semiotic choices interact in multimodal discourses to fulfill particular objectives" (O'Halloran, 2007).

Secondly, according to the thematic pattern approach (Lemke, 1990), science texts are formed "by certain regularities recurring thematic patterns", also called thematic formulations or thematic systems, and a text is made up of "a web or a pattern of relationships between participants". Thematic pattern idea is drawn from SFT, and it focuses on the meaning in the semantic level where participants, processes, and circumstances exist. Thematic pattern strategy mainly involves determining the disciplinary relevant aspects and mapping of the processes, participants, circumstances, and relationship to the meaning of the experience between the participants. This strategy helps to see the particulate level and the types of experiential meaning taking part in the text. In this research, the thematic pattern approach is employed for providing a base to realize ideational meaning as it helps to determine the type of modes and semiotic resources for representing intended meaning (or learning goal).

Thirdly, the construction of science texts is informed from the variation theory of learning (Marton & Tsui, 2004). Variation theory of learning is rooted in "differentiation theories" which claim that "initially vague percepts become more and more differentiated through perceptual learning which is a process of discrimination and discernment"(Fredlund, 2015). Variation theory of learning characterizes learning regarding differentiation of awareness. It states that variation must be done to make aspects in whole for making those aspects discernible. Therefore, the learner can discern and realize the experience of different parts and aspects of the text. This theory posits that every learning content has critical aspects (the most important distinctive aspect of the information), peripheral aspects generally known aspects, and create the theme of the text, and margin those are unrelated aspects to critical aspect. As such, deployment of variation in designing texts to arrange and relate the selected modes and representations defined in the first part of the strategy above. In this research, VTL informs the textual (compositional) meaning of the text.

Lemke (1998) suggests that discourse of science is multi-semiotic (and multimodal) since (1) "each mode provides its specific affordance for meaning-making", (2) "modes used in the discourse collaborate to expand and contextualize meaning". Therefore, a scientific text is assumed as "a network of meaning relationships across modalities situated in the text" (Tang et al., 2011). In the synoptic science texts, written language mode, visual imagery mode, and mathematical symbolism mode mainly work together to instantiate and expand meaning (Fredlund, 2015; O'Halloran, 2007; Royce, 1998). Language mode demonstrates typological "view of reality" (symbolic order of reality) within categorical distinctions where process types, participants, and circumstances constitute experiential meaning within categorical/discrete distinctions (Lemke, 2000). Visual imagery involves topological continuous meaning type where "perception of whole visual takes precedence over perception of the parts that may consist of series of happening within the overall work" (Lemke, 2000). Visual imagery requires descriptive categories. Mathematical symbolism is evolved from language, and it contains discipline-specific symbols and mainly expresses quantitative relationship between participants in the content and includes both typological (categorical) meanings by symbols and topological (continuous) meaning by amounts (O'Halloran, 2007). Thus, there is no single semiotic choice that can afford the whole meaning of natural science. According to Royce (1998), modes semantically complement each other to produce a single textual phenomenon. These three modes work together in certain inter-semiotic mechanisms to produce and expand meaning in texts (Liu & Owyong, 2011; O'Halloran, 2007; Royce, 1998). The concept of mode density or modal density (Norris, 2011) is introduced as a parameter of the use of different modes, which have the best affordances to demonstrate meaning types and experiential meaning types in a science text.

In brief, the multimodal design of pedagogic science texts plays a crucial role in both teaching and learning scientific knowledge in the science classroom. The arguments above focus on the multimodal nature of scientific texts and how the design of the multimodal texts may influence the meaning-making of the scientific content. Therefore, this research explores (1) how the mode level or mode density and (2) the composition of text may affect meaning-making by asking science teachers with the experience of different mode density levels and multimodal text composition. In this respect research questions of this research are as follows. (1) What are the views of science teachers on the effects of the mode density in pedagogic texts on the meaning-making of science contents? (2) What are the views of teachers on the effects of compositional variations in pedagogic texts on the meaning-making of science contents?

METHOD

This research employs a case study method within a phenomenological approach. A case study research is a qualitative approach in which the researcher gathers detailed and in-depth information about the real-life, up-to-date limited system (a situation), or multiple limited systems (situations) over a certain time (e.g., observations, interviews, audio-and-visual materials, and documents and reports), and reveals a situation description or situation themes (Creswell et al., 2007, p. 73). Savin-baden & Major (2013, p. 160) state that the procedure of a case study begins with three steps, namely "defining the case", "bounding the case", and "deciding whether to use single or multiple cases". Based on the aforementioned explanation, this research sought to explore the cases of a phenomenon, namely the meaning-making of scientific knowledge. The objective of this research is evaluation; the disciplinary norm is educational, and the research approach is phenomenology. In this research, the phenomenon is a meaning-making that explores various instances of mono-modal and multimodal pedagogic text types. The evaluation of the different cases of science texts is based on the views of actual practitioners who may use those texts in actual classroom settings.

Procedure and Design of the Texts

To address the first of the research's questions, there were four texts designed for the different mode densities with the same content to investigate the effect of mode density on meaning. Secondly, there were also two different texts involving the same modes and semiotic resources to get views on the effects of variation strategy on meaning-making (second research question). The participants had been asked about the implications of the mode density and variation strategy on the meaning-making of related content. Open-ended and semi-structured interview questions were prepared, and the participants were asked. The data were collected by voice recording or written answers. The participants had enough time for experiencing and evaluating each text and discussing and expressing their opinions on how to make sense of these experiences by assuming that they used their texts in a real-class environment.

Based on the classroom-based studies of Tang et al. (2011) and Fredlund (2015) and the aforementioned theoretical perspectives, this research applied the following text design procedure. Firstly, there are four different texts with the same content, including the decelerating and stopping of a car that is going down a hill and stopping at the traffic lights. The subject is the transformation of mechanical energy into work made by friction. The first text is only made of written language mode, which only narrates and was considered to demonstrate the content in terms of categorical discrete reality. The second text includes mathematical symbolism and equations, which provide to see the synoptic and quantitative experiential meaning relations between the participants (concepts and entities). Besides the typological meaning, the included mathematics symbols in equations imply the amounts of participants. Besides language and mathematics modes, the third text includes visual imagery mode, which only depicts some participants and circumstances. The hill, the car, traffic lights, and the path of the motion are depicted. This image is considered to add the topological meaning of the mentioned elements, and increase modality level and multiply meaning made by the text. The fourth text also included visual imagery mode features, such as spatial relations where image functions to foreground the experiential meaning. In the fourth text, it was assumed that the spatial and mathematical relations can be typologically and topologically described in realistic images and symbolic relations.

Secondly, two texts about the topic of covalent bonding are designed by following a similar procedure in choosing modes and drawing on a variation approach. Both texts have identical semiotic resources and modes. In the first text, all the elements of the texts demonstrate in an equal manner in terms of dimension and location, and there are no connecting elements between the parts of the text. In the second text, according to the criticalness hierarchy of the context, the text within distinct dimensions and location where the critical aspects in bigger size are composed (White, 1982). and central and the peripheral aspects which form the theme are relatively smaller and surrounding the critical aspects. What is more, we put arrows, lines, and coloring to relate different parts of the text. This is considered to facilitate following the sequential processes and logical relations between the elements of the text. In sum, variation around the critical aspects in terms of textual meaning was created by considering the enhancement of meaning-making of the content. The designed texts are given in the Appendix.

Participants

Six science teachers of primary level gifted/talented students with at least 4 years of teaching experience participated in the research. Four participants were female and two of them were male. Participation is based on volunteerism. Sampling was carried out based on the purposive sampling principle in order to gather enough information to show an in-depth depiction of the cases. The participants are given pseudonyms in the demonstration of data.

Data Collection and Data Analysis

Open-ended and semi-structured interview questions were conducted in the following way. The main goal of using the interview method to collect data is not usually to test a hypothesis; on the contrary, it intends to understand the people's experiences and how they make sense of those experiences. The interview questions were prepared on multimodal texts and meaning-making processes, and the participants were asked after the pilot trial of the questions. The questions are given in the appendix. The interviews resulted in open-ended responses. The data were collected in Turkish. The authors transcribed data and translated it into English. This qualitative data was analyzed through thematic analysis. The themes were set by the semi-structured interview questions. The data were coded and categorized. Themes and categories are presented in Table 1 and Table 2. Braun & Clarke (2006) were adopted in the data analysis strategy. The data analysis strategy is presented in Figure 1.

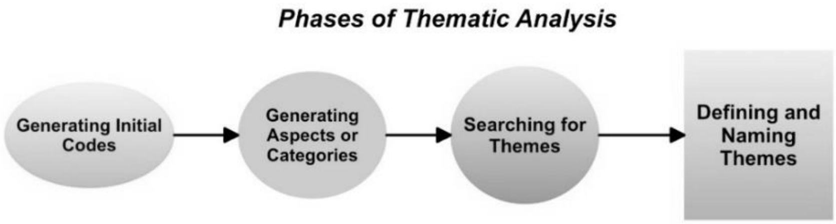

Figure 1. Thematic Analysis Procedure

RESULTS

After conducting the thematic analysis, the aspects and themes regarding how mode density and text composition in a multimodal pedagogic science text were created.

Table 1. Aspects and Themes Regarding Mode Density and Meaning-Making

	Themes			
	1	2	3	4
Aspects	**Mode density can be a determinant factor in realizing meaning types and meaning relationship types between entities and concepts in the content.**	**An increase in the mode level may lead to the concretization of the content and reduce abstractness**	**Mode density may be conceived as a contributing factor to the scaffolding effect of the text.**	**Mode density can lead a semiotic economy to understand the content.**
a	Mode density can be a determinant factor in realizing meaning types and meaning relationship types between entities and concepts in the content.	Realistic depictions of the entities and symbolization of the concepts.	Connecting different units of the text.	Time-saving. One picture can express many things than many words can do.
b	Helps to recognize the meaning relationships which are mathematical and spatial between the entities and concepts in the text.	Depiction of processes within the spatial relations.	Use of arrows.	Synoptic representation of concepts by symbols and mathematical formulas

Mode Density Can Be a Determinant Factor in Realizing Meaning Types and Meaning Relationship Types Between Entities and Concepts in The Content

This theme consisted of teachers' responses and views on the texts' eligibility on demonstrating typological meaning (categorical) and topological (qualifying) meanings of concepts and entities embedded in the texts. Second, the text's power to demonstrate the process took place in the content and the meaning relationship types between concepts and entities (mathematical and spatial relationship). In other words, this theme was pertinent to modal affordance to make meaning related to content. The biggest factor that enabled us to see differences related to these topics was the different responses given to questions after each text and the responses from the overall evaluation. The following is the summary related aspects to this theme, and the explanation of how reached those aspects.

Mode density can be a determinant factor in realizing meaning types and meaning relationship types between entities and concepts in the content

This aspect was based on the recognition and discernment of the entities and concepts taking part in the content. As the mode density increases, there had seen no difference in the recognition and discernment of the number of entities (typographic meaning). However, there were some differences in the topological meaning of the entities as the participants passed to the next texts. For example, one of the participants, Pelin, stated that in Text 1, he saw an inclined plane, a hill, a car, and traffic lamb, while in Text 3, he saw an inclined plane, a car moving down on the hill, starting and points of the movement on the hill, the place where the car ceases its move, and traffic lamb.

However, the differences were more observed in the numbers of different concepts (typological meaning). Although all texts had the same entities and concepts, the participants responded to a greater number of different concepts when the text changes. The change was mainly typological in that the participants added a new concept or added a sub-category of a concept they had already recognized. To illustrate this aspect, the other participants, namely Sude, responded that in Text 1, the concepts compiled kinetic energy, mechanic energy, conservation of energy, total energy, friction force, and work. Meanwhile, in Text 3, the concepts compiled work, decelerating, height, initial velocity, final velocity, and resting. Whereas, in Text 4, the concepts compiled resting, distance, direction, negative direction. Thus, as the mode density increased, discernment of new types and sub-types of concepts were expressed.

Mode density helps to recognize the experiential meaning relationships between the entities and concepts in the text

The participants responded that as the mathematical modes (formulas) added, they easily recognized the quantitative relations became more easily discernible. The responses were found regarding quantitative relations especially when the second text was reconstructed with written language and the mathematic mode was presented.

One of the participants, Ebru, stated that the use of symbols and formulas helped to see mathematical relations between concepts. Thus, it facilitated to infer that the total energies at the initial position and final positions equal.

Meanwhile, Eda as one of the participants in this research, revealed that the inclusion of mathematical formulas instead of fully written language was a better idea since the calculations of energy transformation were simple.

An Increase in the Mode Density May Lead to The Concretization of the Content and Reduce Abstractness

The data revealed that the use of images or figurative elements (symbols, icons, arrows, etc.) helped to concretize entities, concepts, or processes. The participants generally stated that icons and symbols of concept were able to envisage various aspects of that concept, an image of an entity was able to demonstrate qualitative characteristics, or arrows were able to represent the direction of a movement.

Realistic depictions of the entities and symbolization of the concepts

This aspect was more related to image mode in the text. The data revealed that the use of images or figurative elements (symbols, icons, arrows, etc.) helped to concretize the concepts or entities. An iconic model of concept was able to envisage various aspects of that concept; an image of an entity was able to demonstrate qualitative features.

In the case of Text 4, Ebru stated, "…the image representing the hill is good enough to see the pathway where the movement of a car takes place and where the friction force is exerted…" Eda also stated, "this text (Text 4) demonstrates the change in the height better…" Therefore, the change in the potential energy is concretized.

Depiction of processes within the spatial relations

One of the most noticeable responses regarding the affordance of modes to demonstrate the spatial relations between the car at the initial position and the same car at the final position was the discernment of the initial and final positions of the car. Another point was the depiction and description of processes. As said earlier, the content was about the process of energy transformation from one position to another. The participants generally stated that the image mode and the semiotic resources (different colors, lines, etc.). The participants responded that what happens in the first and last locations was more recognizable compared to the process between the different locations. Some of the participants' responses related to this aspect are represented as follows.

Hasan: *…arrows in this text (Text 3) demonstrate the velocity and magnitude of the velocity as the car decelerates…*

Pelin: *The third text presents realistic images that depict the process. The image helps me to understand the movement of the car (process) better*.

Eda: *…the image makes it easier to figure out the initial and final states of the moving car…*

In comparison, the participants stated that the image mode included Text 3 and Text 4 led to depiction and decreasing the abstractness more than Text 1 (only written language mode) and Text 2 (written language mode and mathematical mode).

Mode Density May Be Conceived as a Contributing Factor to the Scaffolding Effect of the Text

This theme was related to the demonstration of the power of text directions on the reader to follow the sequential processes and relate the participants (entities and concepts) in the content. How did the text help or assist to understand the content can be conceived as the scaffolding effect of the text? The aspects regarding text scaffolding and those are cultivated from the interview responses are as follows.

Connecting different units of the text

Texts had different units in conveying pieces of information. The participants often expressed that the use of various modes facilitates the relationship among different parts of the content. Those parts may include explanations, calculations, depictions, or questions.

Ebru: *Following the flow of the process is easier in this text (Text 4) since the explanations and other units follow each other in a stepwise order. Calculation of energy at the initial position and demonstrating this calculation under the initial position image, doing this for the final position, and showing the friction force next to the path make the content more understandable for me…*

Eda. *This text (Text 4) relates the total energy in the first situation and the total energy in the last situation. By relating those two situations calculation of the energy consumed by friction becomes easier…*

These findings revealed that representing different meaning units of content with different modes and relating them in an organized manner could increase the embeddedness level of the reader inside the text.

Use of arrows and lines

This aspect deals with the use of arrows and lines in texts. As mentioned earlier, a view on the use of arrows was attributed to demonstrate movements inside the text and relation of different units of text specified in the aspect "Mode density can be a determinant factor in realizing meaning types and meaning relationship types between entities and concepts in the content". In addition to those aspects, the participants expressed that arrows in multimodal texts were able to help readers to notice a specific aspect or representation. In other words, arrows could direct the readers' attention onto a specific field in the content. These comments and responses were seen especially in Text 4. Some arrows were used to take the readers' attention to the formula of conservation of energy. Therefore, the readers focused on the summarizing point of the text.

Pelin: This text (Text 4) directs me to focus on the formula of conservation of energy and relate this to other parts…

Eda: *This text (Text 4) is more dynamic. It is most likely to be understood without any assistance from a teacher…*

Teachers also commented on the text structures overall. They mainly responded long when Text 4 was demonstrated. The text structure was well-designed with various modes that helped readers to focus on.

Mode Density Can Lead a Semiotic Economy to Understand the Content

This theme was related to the text's feature on how long it took the readers on it, and how much effort the readers consume to understand the content. We used the term semiotic economy that can be considered as making-meaning by using a smaller amount of semiotic resources (or just necessary) and the situation when the text is not parsimonious (DiSessa, 2004).

The use of various modes can be time-saving for readers

This aspect engaged to time spent for understanding the content depicted by the text. The participants generally stated that the use of images and symbols prevented reading many sentences and words, thus readers can save time while reading a text. The typical argument is that "one picture can stand for many words". The participants' responses related to this point are presented as follows.

Eda: *In this text (Text 3) without the need for long sentences, the process is depicted using image… Inclusion of image to text accelerates meaning-making. …It shortens the time to understand the content.*

Cem: *Use of the image in this text (Text 3) makes the text more meaningful since the image can represent meanings that many words cannot do…*

Synoptic representation of concepts by symbols and mathematical formulas

Another aspect that leads to the semiotic economy in multimodal texts was the use of symbols and formulas. This situation led to the economic use of semiotic resources in the text.

Ebru: *In this text (Text 1), only words are used. Mathematical symbols and formulas might be used…* Hasan: *the mathematical formulas in this text (Text 2) represent the content which might be represented by the use of many words…*

Eda: (Text 2) *…use of formulas helps to understand the transformation of energy more easily…*

In the evaluation, the participants were asked for their choice of text to teach this content. Five participants chose Text 4, whereas one participant (Ebru) chose Text 2. Interestingly, this participant previously stated that "following the process and actions taking place in the content is easier with Text 4".

Ebru: I choose Text 2 since the use of different resources may lead to distractions. Written language mode and mathematical mode seem sufficient…

Eda: *Text 4 is more organized and easier to focus on and relate the different pieces of information of the text. It is the most attractive and the most convenient to depict the flow of the process…*

Sude: *Text 4 concretizes the concepts and processes taking place in the content. Therefore, for students, it is easier to understand the content of this text…*

Effects of Variation Strategy in Multimodal Text Composition on Meaning-Making of Science Content

The aspects and themes regarding how variation strategy in the compositional structure of multimodal pedagogic science text was created to make the content more understandable.

Table 2. Aspects and Themes Regarding Text Composition and Meaning-Making

	Themes	
	1	**2**
Aspects	**Variation strategy may lead to higher discernibility of critical aspects in multimodal pedagogic science texts.**	**Variation strategy can help to design complete and coherent multimodal pedagogic science texts.**
a	Critical aspects are different in two cases.	More organized text structure
b	The hierarchy of criticalness is different in two cases.	Connections between smaller units

There were two multimodal pedagogic texts of "covalent bonding" designed in this research. For the first text, modes were chosen and randomly in the text. For the second text, modes were chosen as in the first case by adding the textual (compositional) meaning features of the text in accordance with variation theory of learning (Marton & Booth, 1997) and specific procedures proposed by (Fredlund et al., 2015). Several specific questions related to meaning-making and understanding of the content were asked. By following the thematic analysis procedure, aspects and themes were initially determined.

Variation Strategy May Lead to Higher Discernibility of Critical Aspects in Multimodal Pedagogic Science Texts

This theme was related to the possibility of text structure to make the concepts, entities, or any of the aspects of the content discernible regarding their importance and criticalness. Since the variation theory of learning emphasized the degree of differentiation in the demonstration of content, variation level in the text was assumed to make the elements of content more discernible. Thus, the differentiation and discernment were expected to be built by foregrounding and relating to strategies within the text.

Critical aspects are different in two cases

This aspect was related to the perceived entities, concepts, and related aspects by the content. The most attractive factor to build this aspect was the difference of recognized concepts and related aspects between the two texts. In the case of Text 2, the participants recognized additional concepts and aspects. Ebru, 3, 5, and 6 added extra concepts in the second case (Text 2).

Ebru-*Text 1: Atom, electron, orbital, and steady-state... Text 2: Orbital, electron, steady-state, atom, electron, and electronegativity.*

Pelin- *Text 1: Atom, electron, chemical bonding, orbital, and atom models. Text 2: Atom, electron, chemical bonding, orbital, atom models, elements, and element symbols.*

Cem- *Text 1: nonmetallic, atom, steady-state, electron share, and chemical bonding… Text 2: nonmetallic, atom, steady-state, electron share, chemical bonding, orbital, number of electrons in the last shell, and valence shell.*

The findings showed us the variation strategy within the multimodal text led to the recognition of new concepts and aspects such as electron pairs share.

The hierarchy of criticalness is different in two cases

This aspect was related to recognition and discernment of important and critical aspects of the content. All information or knowledge did not have similar importance. Texts had themes and a particular point to emphasize. Variation strategy was believed to foreground critical and important aspects of the content. The participants were asked about the criticalness hierarchy of information and knowledge embedded in the text. The same question was asked for two cases. The participants mostly seemed to change their criticalness hierarchy.

Hasan- *Text 1: covalent bonding, chemical bonding based on electron share… Text 2: Share of electron pairs, covalent bonding, and chemical bonding.*

Sude- *Text 1: covalent bonding, and electron share… Text 2: electron pairs share in the valence shell, and covalent bonding.*

These findings showed that there were changes in the views in which the participants stated the critical aspects of the content.

Variation Strategy Can Help to Design Complete and Coherent Multimodal Pedagogic Science Texts

This theme was related to the completeness of the text that referred to "representational goals which instruct the model-maker to include every known aspect of the target system(s)"(Hay & Pitchford, 2016). This inferred that the representational form of the text should include all the information and aspects. The participants generally stated and implied that variation strategy may help to design a pedagogic multimodal text, completely and inclusively. This theme was constructed by the determination of the following thematic aspects.

A More organized text structure

This aspect was related to the determination of the aspect hierarchy before designing the text. The participants stated that the text structure becomes organized around a purpose with the dimensional and locational arrangements regarding the criticalness hierarchy of aspects.

Hasan*: The text design strategy employed in Text 2 changed the foregrounded meaning of the text. In Text 2, the share of pair electrons are well foregrounded. ...the peripheral aspects and critical aspects are differentiated thanks to text structure…*

Connections between smaller units

This theme was related to the use of connections between the aspects of the text. In Text 2, lines and arrows were used to connect different information units of the text. The participants expressed that the content was more understandable due to the arrangement in connections and the use of different semiotic resources for smaller units of the text.

Ebru: *(Text 1) The foregrounded aspects are shown by the use of images…* (Text 2) *although images are used in the first text, those images are related by connective resources in the second text. Therefore, besides images and their connections with other aspects, this text makes the content more understandable. What smaller units (peripheral aspects) are well related to the critical aspect.*

Although almost all of the participants commented on the text design strategy and emphasized aspects, only two participants, Hasan and Pelin, attributed the related differences to dimensional and spatial differences of representations in the text structure. Meanwhile, the rest stated the difference without giving sufficient reasoning. When we asked participants which of the text they would choose if they taught this topic, all the participants chosen the second text that was designed regarding variation strategy. Pelin stated his preference for the second text due to the attractive text structure, the more recognizable the choice of contrast, and the more organized text structure to be understood.

DISCUSSION

The findings show that, according to the participant views, the use of various modes and creating variation around the text composition can enhance understanding of content. This is consistent with Tang et al. (2011) and Tang et al. (2014) who found that the use of diverse modes may help to recognize and understand diverse aspects of facets (Airey & Linder, 2009) of the disciplinary knowledge. However, it should be used intentionally based on a conscious pedagogic strategy. This idea is in line with Herrlinger et al. (2017) and DiSessa (2004) who claimed that the use of unnecessary semiotic resources and modes (parsimonious text structure) can lead to distraction, and may prevent appropriate learning. Therefore, every text must not be multimodal. In addition, this research sought to investigate the dependence of the modal structure of texts on the meaning types and meaning-relationship types they represent and this modal structure should be designed based on pedagogic reasoning (Patron et al., 2017) and intentions embraced by teachers. The participants clearly stated that the use of various modes could demonstrate participants (entities and concepts) better if they were consciously chosen. Semiotic modes and the compositional elements (colors, size, shading, shapes, etc.) should be collaborated to represent the topological (qualitative features) and typological (category) meanings in a similar manner proposed by Lemke (2000) in his mixed-mode semiosis approach. The participants proposed that the image mode has more meaning-making potential (affordance) to represent topological meaning while language and mathematical mode have more potential to demonstrate typological meaning. This finding is consistent with the findings of Fredlund (2015). The entities or concepts in a text create a process or processes that are dynamic. Akaygun & Jones (2014) proposed that those processes were best represented by language mode. The results were similar, but some participants stated that the use of arrows can also represent movements and their directions, and do but for a limited number of movements such as forward movement or circular movement. Another aspect in the first theme was the demonstration of meaning relationships between entities or concepts. The participants did not directly refer to any specific meaning relationship, but it conceptualized their views under mathematical (quantitative) and spatial relationships parallel to the categorization of Tang, Tan & Yeo

(2011). Meanwhile, in the second text, the participants clearly stated that mathematical formulas and symbols made the quantitative relations and calculations more recognizable rather, and students were able to see the change in the energy at initial and final positions easily. These findings are consistent with the classroom research conducted by Tang, Tan & Yeo (2011).

The second theme shows that mode density was able to increase concreteness, and reduce abstractness. This finding is in line with Chandler (2007, p. 74) about modality that is assumed to change "the ontological status of the message". Because of realistic representations and demonstration of the process in an iconic manner (Tang, 2013), the participants saw that currently, learners were able to imagine what happens in the text and they can think in the direction. The third theme is derived from the detailed views of participants. Their views simply referred to that the use of modes that are appropriate to the intended meaning and semiotic resources, for example, arrows and directional may increase the scaffolding potential of the text. This potential seems to be achieved by the compositional text elements described by O'Halloran (2007), such as arrows, lines, or colored zones

The last theme about mode density and meaning-making stated that multimodal text was the semiotic economy that helps the learner understands in a shorter time and with lesser efforts. This aspect was directly expressed by the participants. Especially, one participant stated that "one image can stand for many words". What is more, for the learners who know the symbols of concepts, the use of concepts can lead to the reading of many words and these symbols enables to construct the mathematical formulas and equations. In the evaluation part, five of the participants were in favor of the fourth text that we designed in an assumption to have the highest mode density. This was inferred from the views of these experienced science teachers, the conscious design of multimodal science text within pedagogical aims was able to lead to an increase in the meaning-making of the content.

How can arrangements of modes and text composition based on variation theory of learning affect the meaning made from the text? The first theme was the arrangement of modes in accordance with variation strategy that was able to help to foreground the important and critical aspects and points inside the text. One of the participants clearly stated that the arrangement of modes and semiotic resources was able to lead a change in the emphasized message or aspect. As such, the meaning made can be altered. Another point was that variation strategy helped teachers design complete and holistic text. The participants stated that the second text related all the aspects and information so that it was easier to relate all aspects and reach an overall understanding with such an organized text. In other words, since variation strategy engaged to discriminate the information pieces of content as critical, peripheral, and margin (Marton & Tsui, 2004) and putting those to text in discernment level in accordance with this hierarchy, it was easier to start with the most important part and go down. Therefore, the conclusion was the variation strategy could ensure the designer in creating a compositionally coherent text.

CONCLUSION

Since science texts used in teaching and learning convey and demonstrate scientific knowledge, they are essential elements for meaning-making and learning of the science content (Kloser, 2013). Especially, the texts used during lessons can help better instruction (Jewitt et al., 2001). By drawing on the participant teachers' views, this study claims that text design strategy and text structure can affect meaning-making and understanding of content. Therefore, with an assumption that is the communicational resources affect learning (Jewitt, 2008), pedagogic science texts provided to students should be consciously chosen and designed. Multimodal text design strategies should be embraced by science teachers for the teaching of scientific knowledge.

This study has limitations about the extent of the context. The number of designed texts should be increased and applied to other science topics. Future directions should be focusing on different science topics and different levels. Furthermore, the effects of multimodal text design on student learning should be explored in classroom settings. Moreover, this study is a part of the first author's doctoral research.

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APPENDIX: DESIGNED TEXS AND INTERVIEW QUESTIONS

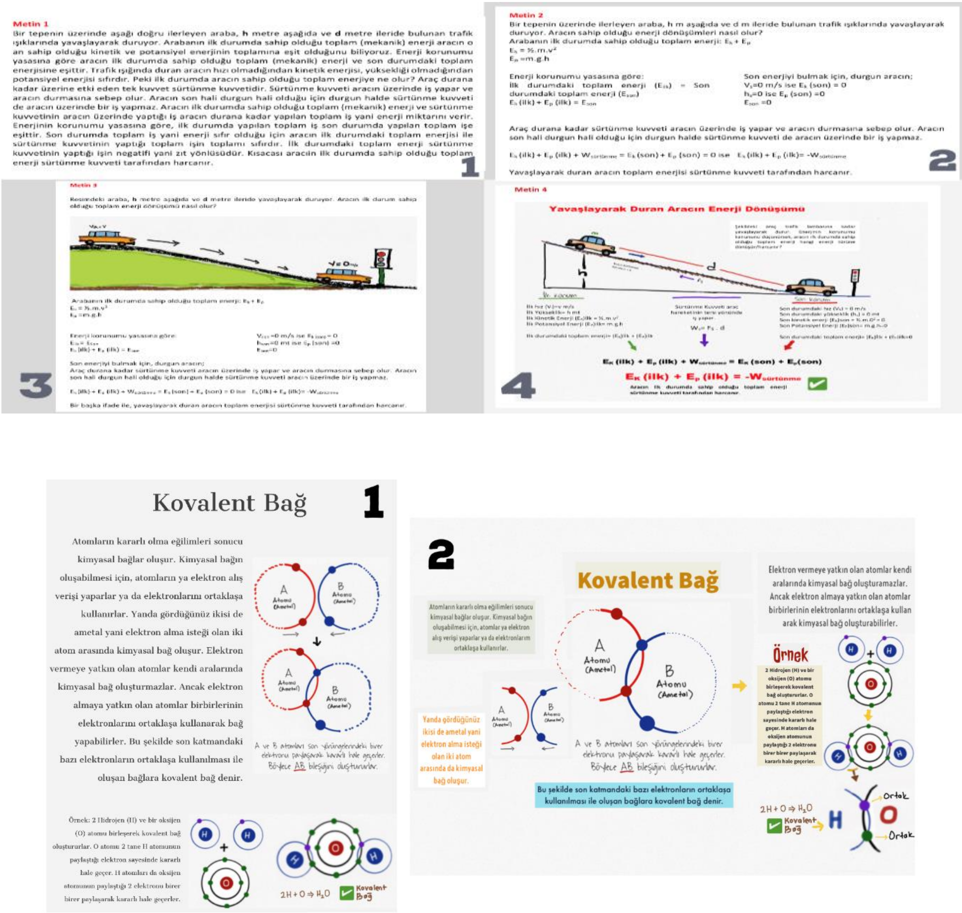

Figure 2. Four Texts of Same Science Content with Different Mode Densities and Text Variation

Table 3. Interview Questions

Text	Q.	Part 1
1	1	When you look at this text, can you specify the concepts and entities in the text?
	2	How are the concepts specified by the text associated with each other in terms of meaning-making?
2	1	When you look at this text, how the processes are expressed differently than the previous text. Can you compare the text structure of the previous text with the structure of this text?
	2	How do the modes you express as new in this text relate to the concepts that the text has? What kind of meaning relationship do they represent?
3	1	Can you structurally compare this text and the first 2 texts?
	2	What are the concepts and beings expressed by the picture?
	3	We see that there is a picture in this text. What does this picture tell us?
	4	If we compare it to the first and second text, can the meanings of this image mean the writing modes in these two texts? If he does or can't, why?
4	1	What are the concepts and entities you notice in this text?
	2	What signs (modes) are these concepts and entities presented with?
	3	How meaningful do you think the sources used in this text can express the content compared to other texts?
	4	If you compare this text with other texts, what difference(s) are there structurally?
	1	Which design do you prefer to use in your instruction? Why?
Text	**Q.**	**Part 2**
1 % 2	1	When you read/review the text, what is the preliminary information necessary to make sense of the text?
	2	Can you sort the content/topic that the text means from general to specific?
	3	What are the modes used in this text?
	4	What is the feature/subject/subject that you notice most, which is highlighted in this text?
	5	What kind of strategy is the emphasized/or aspects made different?