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Apuntes Universitarios

Nivel de dificultad de las representaciones multimodales utilizadas por los profesores de ciencias de alumnos superdotados

The difficulty level of multimodal representations used by science teachers of gifted students

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Resumen

En vista de la tendencia de los estudiantes superdotados a experimentar desinterés por los conceptos comunes y explicaciones demasiado simplificadas, junto con su inclinación hacia materiales de aprendizaje intelectualmente desafiantes, este estudio tiene como objetivo averiguar cómo los profesores de ciencias responden a estas necesidades únicas de aprendizaje por medio de representaciones multimodales. Para ello, el estudio investigó el nivel de dificultad de estas representaciones con respecto a las relaciones intersemióticas. El presente estudio es una investigación cualitativa que incluye el Análisis Sistémico Funcional Multimodal del Discurso (SF-MDA). Los datos obtenidos de representaciones multimodales -318 representaciones de todos los diferentes grados (5°, 6°, 7° y 8°)- fueron analizados de acuerdo con el marco analítico desarrollado en este estudio con respecto al enfoque SF-MDA. Los resultados mostraron que los profesores generalmente utilizan formas primitivas de representaciones multimodales. El número de formas avanzadas de representaciones multimodales es mínimo. Se llegó a la conclusión de que es necesario organizar programas de capacitación docente para dotar a los docentes de los conocimientos y habilidades necesarios para elegir y diseñar el nivel superior de representaciones multimodales para que satisfagan las necesidades educativas de los estudiantes superdotados.

Palabras Clave

estudiantes superdotados, formación docente, multimodalidad, representaciones.

Abstract

In view of the tendency for gifted learners to experience disinterest in commonplace concepts and oversimplified explanations, coupled with their inclination towards intellectually challenging learning materials, this study aims to how science teachers respond to these unique learning needs by means of multimodal representations. To do this, the study investigated the difficulty level of these representations with regard to intersemiotic relations. The present study is a qualitative research including Systemic Functional Multimodal Discourse Analysis (SF-MDA). Data obtained from multimodal representations -318 representations from all different grades (5th, 6th, 7th, and 8th)- were analyzed according to the analytical framework which developed in this study regarding the SF-MDA approach. Results showed that teachers generally use primitive forms of multimodal representations. The number of advanced forms of multimodal representations is minimal. It was concluded that there is a requirement to arrange teacher training programmes in order to equip teachers with the necessary knowledge and skills about choosing and designing the upper level of multimodal representations in order for they meet instructional needs of gifted students.

Keywords

gifted students, teacher education, multimodality, representations.

1 Introduction

New information flow channels and the digital world changed dispositions towards knowledge construction, meaning making, and access to information (Mayer & Moreno, 2003). Media tools in the digital world provided greater facilities for disseminating and accessing different forms of texts which include more detailed definitions of knowledge (Bezemer & Kress, 2008; Kress & Selander, 2012; Tang, 2016). These texts now provide opportunities to present and construct knowledge using different modes (such as written and spoken language, images, and gestures), hence they are called as multimodal representations (e.g., infographic, PowerPoint presentations, animations, videos) (Airey & Linder, 2009; Kress et al., 2001).

In this context, it is apparent that scientific knowledge is also constructed and made accessible to students with multimodal representations during teaching and learning process. In the real or digital classroom environment, scientific knowledge or concept is represented and communicated through orchestration of semiotic modes (Kress et al., 2001; Lim, 2019). Within this perspective, Tang and Tan (2017) identified a scientific concept as 'a network of semantic meanings, assembled across multiple modes of representations' (p.22). Wu et al. (2019) indicated that integrating multiple modalities has become the cornerstone of scientific practices in scientific communication. Science teachers use different modes to present scientific ideas to support students in the meaning making process. In other words, science teaching is a multimodal dynamic activity where modes in different dissemination tools are elaborated, orchestrated, and where the designing of new representation is re-configured and re-contextualized in new media (Yeo & Nielsen, 2020). The aforementioned dynamic activity may be differentiated based on its content delivery approach, which can be tailored to suit the learner's proficiency level. This tailored approach is particularly pertinent in the case of gifted learners, who often require more challenging learning materials.

Regarding gifted students in the science classroom, they are getting bored of over repetition of basic ideas and over generalized explanations; they demand nuanced and detailed explanations and look for challenging teaching materials (Taber, 2014). The situation is related with the characteristic of complexity contended by Van Tassel-Baska (2023). As stated by Fisher and Oyserman (2017), challenging tasks are seen valuable, interesting, and motivated tools to complete by them. That is, scaffolding the gifted students through appropriate level of challenge with detailed content is required to meet the needs of gifted students' instructional needs (Little, 2012). On the contrary, since their academic needs are unmet (Ridgley et al., 2022), unchallenging work leads them to experience underachievement and task avoidance (Snyder & Linnenbrink-Garcia, 2013).

At this point, multimodal representations provide teachers with many opportunities in order to meet these needs mentioned above as followings. Studies have shown that the dynamic activity results in important learning opportunities including learning disciplinary content knowledge and inquiry practices (Kocaman, 2022; Moro et al., 2019; Tang & Danielsson, 2018; Treagust et al., 2017; Tytler & Hubber 2016; Waldrip & Prain, 2012).

A growing body of research has shown that it is challenging to make sense of information presented multimodally (Bateman, 2017; Qiuping, 2019). When it comes to learning characteristic of gifted students, they are cabaple of transfering their learning to another contexts (Siegle & Powell, 2004), which is the core of multimodality approach. Multimodality may provide gifted students to express themselves creatively and imaginatively by reciprocity between different modes and to re-process their thinking in another mode

(Bathcelor, 2018). As each mode has unique potentials and limitations for meaning making and description, and also integrating them results in elaboration and extension in meaning making (Lim, 2011; Selander & Kress, 2010), detailed and nuanced explanations can be actualized through multimodal representations. Multimodality may offer gifted students to investigate meanings in a new clear way. For instance, Jewitt (2008) found that different modes of representation encourage students to construct knowledge in different ways. McDermott and Hand (2013) advocated that exposing to and engaging in multiple modes encourage students to be more creative and constructive in the process of developing and creating scientific ideas. Lim (2011) found that orchestration of modes enables teachers to attract students' attention, motivate and encourage them to participate in the classroom. Taber and Akpan (2016) stated that orchestration of modes to transfer multiple meanings encourages readers to reject a single interpretation of the concept in knowledge construction. Oz and Memis (2018) indicated that using multiple modes provided students to describe and construct the same concepts in different demonstrations representationally, figuratively, experimentally, and mathematically.

Overall, it has been stated in the literatere that preventing gifted students from feeling bored and motivated, appropriate level of challenge should be provided through differentiating content, process and product (Kaplan, 2009). By taking into account the content differentiation, multimodal approach presents many opportunities to design teaching materials within varied levels of difficulty and to reorganize and intensify the content as well. Owing to the fact that, within the perspective of systemic functional theory and social semiotics approach to multimodality, the challenge level of multimodal representations is actualized through intersemiotic relations in which semantic expansions of co-contextualizing and re-contextualizing relations occur between modes (O'Halloran, 2007). Intersemiotic relations are important attributes of multimodal texts which create integration of words and images rather than a mere linkage between the two modes. These relations guide revealing how visual and verbal modes are merged to establish a semantic integration, in which image-text relations are formed to multiply the meanings (Yeo & Nielsen, 2020; Zhao et al., 2014). The relations are described in the theoretical framework part detailly. Therefore, investigating intersemiotic relations between modes will guide us to comprehend the challenge level of multimodal representations. Moreover, multimodal analysis, which is mostly applied in the field of linguistics (Hiippala, 2014), is not well known and applied in science education and science education for the gifted (Tang, 2023). Since the modes in multimodal representations are intertwined with each other, the study of these representations will also contribute to empirical studies on how to use representations in science teaching for gifted students. However, the few analyses that have been conducted have focused on school textbooks (Rusek & Vojíř, 2019) and have not dealt with what teachers use, nor have they examined the semantic relationship between visuals and text (e.g., Akcay et al., 2020).

In this respect, the study aims to examine how the challenge level of multimodal representations is realized with respect to intersemiotic relations between image and text in science education of gifted students. Thus, the study demands answers of the following research questions:

1. What types of intersemiotic relations are used in multimodal representations?
2. About intersemiotic relations used in science education of gifted students;
    a. What is the difficulty level of multimodal representations?
    b. How do they change with respect to grade levels?

1.1 Theoretical Frameworks

The study is based on two theoretical frameworks. The former is systemic functional theory which is a theory of language-based meaning (Halliday & Matthiessen, 2014). The latter is a social semiotic approach on multimodality which extends language dependent meaning beyond multiple modes (Kress, 2009; van Leeuwen, 2005).

1.1.1 Systemic Functional Theory (SFT)

SFT focuses on understanding and evaluating the meanings in the context in which they are used. SFT claims that potential meanings of semiotic sources -a resource used for meaning making such as language and image- are presented in system networks and also metafunctionally organized. In other words, SFT analyses meaning in a system (semiotic networks between modes, intersemiotic relations) considering functions (Lim, 2011).

The concepts of system network and function are key terms in SFT. SFT models the semiotic resource as a system of interrelated options. These interrelated sets of options are called the system network. Meaning is realized through exchanging by choosing available options in the system network.

The system network enlightens the present study in accounting for intersemiotic relations between semiotic resources of image and text (written text). It manifests all types of semantic relations provided by integration of image and text modes. For instance, in the system network of image and text, the entry condition -a type of semantic relation called concurrence- proposes four sets of semantic options: decorational, exemplary, representational, and exposition. That is, relations in these options can be each of them. For example, if 'concurrence' relation is chosen, the relation can be further designed as 'decorational', 'exemplary', 'representational', and 'expositon' (Figure 1).

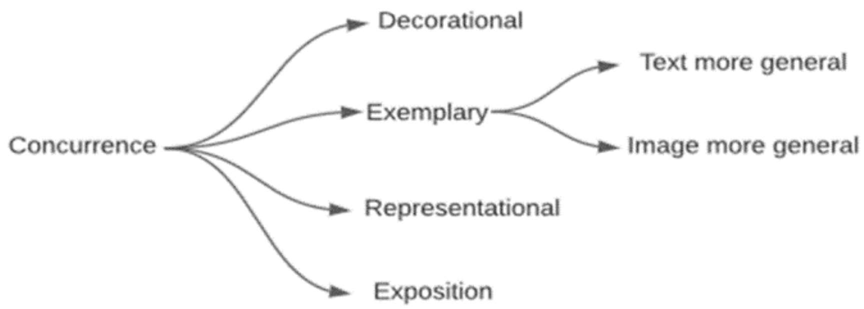


Figure 1. A sample of system network.

The second key term of 'function' means what roles semiotic sources play, namely in the field (what is happening), participants, and mode of discourse (Lim, 2011). This means that semiotic resources have meaning potentials that are not only represented in the system network but also, they are organised metafunctionally. They have three metafunctions: (1) Ideational meaning which is used for constructing the nature of events, including the objects, participants, and circumstances to make sense of human experience (Halliday, 1978; Halliday & Matthiessen, 2014). It focuses on *knowledge*. (2) Interpersonal meaning, which is used for enacting social relations, identifying how the semiotic resource positions the learner in relation to knowledge. (3) Textual meaning refers to the arrangement of ideational and interpersonal meaning in a text.

When considering these metafunctions in science education context, the first one is about description and explanation about the disciplinary specific content knowledge, and the scientific conceptual aspects. The second is about the relationship between teacher and student during pedagogical discourse, and the last one is about organizing former two structural forms in the text (Chan & Unsworth, 2011; Unsworth & Chan, 2009). The present study just focuses on ideational metafunction is realized through image and text with regard to the system network of these modes.

1.1.2 Multimodality

Multimodality concerns with representations and communication processes including more than one mode, for instance image, gesture, gaze, posture, spoken words, and writing (Daniellson & Selander, 2021). In this context, multimodality claims that meanings are made through multiple modes, of which language is only one (Kress & van Leeuwen, 2002). Namely, language is only one part of representation and communication. Modes never exist alone in a text. Since multimodality views meaning beyond spoken and written language, it addresses the question of how modes are integrated to make meaning (Jewitt, 2008). It examines how human beings make meanings through orchestration of various modes within and across representations during communication (Airey & Linder, 2009; Kress, et al., 2001). In this context, Jewitt (2008) indicated that each mode has dynamic and fluid characteristics in meaning making process, rather than static skill replication and use. Based on SFT, language mode has three metafunctions regarding meaning. In this context, multimodality broadens the term of metafunctions considering other modalities (visual, auditory, gestural, etc.).

Multimodality guides this study by explaining the concepts of mode, modal affordance, and multimodal representations. Mode is an organized set of semiotic resources in sign systems, it is used for articulating meaning (Jewitt, 2008). Writing, spoken words, image, gesture, and pose can be accepted as a mode, because each one has different organizational structures in order to convey socially shaped meanings (Kress, 2009). As O'Halloran (2011) stated that mode is used to describe language, image, gesture, and etc which orchestrate across sensory modalities (visual, aural, tactile…) in multimodal discourses, events, and texts.

Modal affordances refer to the perspective that each mode has potentials and limitations for meaning making (Kress & Selander, 2012). Since each mode has specific logic, grammer, and regularized sets of semiotic sources, modal affordance can be described as which parts of meaning can be easily and most appropriately realized, expressed, and represented easily by which mode (Jewitt, 2003). This issue arises the question of what mode is best for, what arrangements are best for given its social context. In this regard, multimodality plays a critical role in investigating the affordances and potentials in the different modes as well as how they integrate coherently in their joint co-deployment (Lim, 2011). At this point, multimodality states that meaning is realized through the orchestration of different modes and investigates the relationship and embeddedness between modes in multimodal representations (Kress, 2003; Bezemer & Jewitt, 2010).

Representations refer to tools that are used for organizing complex information and help readers to make meaning of complex subjects by presenting knowledge in a coordination between modes (Tang et al., 2019). Representation can be described as a device used to symbolize a type of information or an idea via conceptualization of an item in a certain mode (Andersen & Munksby, 2018). They are used for communication purposes. Representations can be classified from monomodal text (the form of a written text, a graph which includes symbols, a diagram) to multimodal text (infographics, simulation, animation) (Lemke, 1990). Any multimodal text or representations were described as an interwoven combination of various modes (Airey & Linder, 2009; Andersen & Munksby, 2018).

2 Methods

2.1 Participants and Settings

Participants were chosen by convenience sampling. Teachers of gifted (ToG) were invited to participate in this study with online and face to face meetings. In these meetings, the process and purposes of the study, the role and responsibilities of researchers and practitioners, what is expected from them, and the calendar about this research were shared clearly. The six ToG voluntarily accepted to participate in this research. Two of them are male, the rest of them are female. One of them has a bachelor's degree, two of them have a master's degree, two of them are PhD candidates, and one of them has PhD degrees. They are all experienced in science teaching for gifted students, the average teaching experience was 7 years. They work in different regions of Turkey, but schools have the same attributes.

These schools, called Science and Art Centers (SACs), have one or two science teachers. These schools are designed to educate gifted students as an enrichment program after formal education. Each city has at least one SAC in Turkey. SACs select students according to some criteria. Firstly, prospective students are chosen by teachers to take the group scanning exam. Then, successfull ones take individual exams regarding general ability, music, and art. If they succeed in these two sequential exams, they are accepted as gifted (Bildiren, 2018). SACs provide enrichment education which aims to develop their thinking skills, problem solving skills, and ability (Güçyeter et al., 2017). SACs try to realize these aims by following four educational phases: orientation, supporting education, recognition of individual talents, and development of special talents. The former refers to expose to activities that introduce SACs. The latter means students engage in activities about higher order thinking skills. The third means that students select activities in some disciplines according to their interests, the last one refers to generate projects in specific subjects.

2.2 Data Collection

The study focused on multimodal representations used by ToGs in four different grades (5th, 6th, 7th, and 8th) with three different subject areas (biology, chemistry, and physics). The researchers considered two main criteria while choosing multimodal representations. These were:

- These multimodal representations must be used in science education of gifted students,
- These multimodal representations must be used in all subject areas such as physics, chemistry, and biology.

Within these considerations all different classes and whole subject types were selected in the 2020-2021 spring term. Four different lessons were analyzed for each grade. In 5th, 6th, and 7th grade, biology and physics subjects were only chosen because chemistry is not covered during this term. In 8th grade, all disciplines were covered. There are four subjects covered in fifth grade: biodiversity, environment and human, light, and propagation of light. Regulatory system, endocrine system, sound, and sound speed were analyzed in 6th grade. Topics of mirrors, growth, growth in plants, and lenses were examined in 7th Grade. Electricity, charged substances, environmental science, and climate change were investigated in 8th grade. Based on these criteria, 318 representations were determined.

2.3 Data Analysis

The present study is qualitative research including discourse analysis. The discourse analysis technique used in this study is Systemic Functional Multimodal Discourse Analysis (SF-MDA). Based on the studies of Halliday's (1978) systemic functional grammar (which investigates the meanings made in language mode regarding the ideational, interpersonal, and textual metafunctions), SF-MDA extends this examination beyond other sets of organized semiotic sources (He & Forey, 2018). SF-MDA is identified by Djonov (2005, p. 73) as "an analytic practice which tests the application of the key principles of SFLs to the analysis of semiotic systems other than language and their interaction with each other and with language in semiosis". In this study, the SF-MDA approach was developed to investigate intersemiotic relations between the written language and image modes -which semantically complement each other- in multimodal texts in terms of metafunction of ideational meaning. Investigating intersemiotic relations -where semantic expansions of co-contextualizing and re-contextualizing relations occur between them (O'Halloran, 2007)- between modes contribute to understanding underlying principles for interaction across different modes deeply. In this way, from the SF-MDA perspective, researchers can distinguish what relations make multimodal text visually and verbally complex and coherent.

Data obtained from multimodal representations were analyzed according to the analytical framework developed in this study (explained in detail with examples in the next section). Each representation was coded by two independent researchers under the guidance of the analytical framework. Based on the analytical framework, intersemiotic relations between image-text are determined first, and then classified into two groups and eight categories. Two groups refer to concurrence and complementarity. The former one includes four categories (decorational, exemplary, representational and exposition) from simple to complicated. The latter also consists of four categories (comparative, organizational, augmentation and interpretational) from simple to complex relations.

All representations were analyzed by two independent researchers through dimensions and categories created under the guidance of the analytic framework, first considering the categories and then the codes. To do this, first, researchers divided multimodal representations into dimensions. Dimension refers to a specific aspect of the represented topic. In other words, what each representation in the multimodal whole contributes to overall meaning by referring to only one specific respect. For instance, in a global warming subject, while one representation signifies dimension of causes, the other refers to effects dimension. After determination of dimension, the researchers identified categories of each representation in multimodal representations at regular intervals (15 days). Besides, an expert categorized multimodal representations independently. Finally, the researchers discussed categorizations to reach a consistent classification.

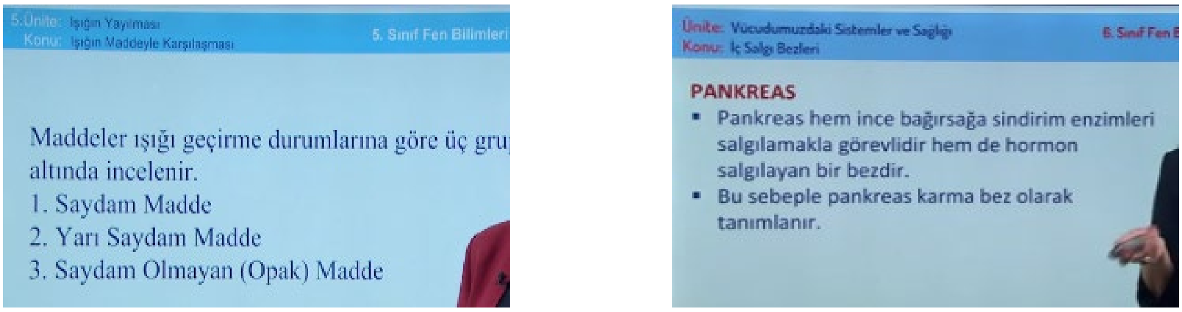
2.4 Development of the Analytical Framework

The analytical framework for investigating intersemiotic relations between image-text is developed based on the grammar-based approach to SF-MDA follows Halliday's (2004) and Martinec and Salway's (2005) and Unsworth's (2006a) lexico-grammatical formulation of logico-semantic relations. They classified logico semantic relations into two general forms as ideational concurrence and ideational complementarity. These classifications enlightened the present study in order to construct a system network of intersemiotic relations between image and text while analyzing multimodal representations through SF-MDA.

The current study extended and elaborated image and text relations by referencing the studies of van der Meij & de Jong, 2006; Chan & Unsworth, 2011; Tippett, 2016; Unsworth, 2014; Keles; 2016; and Meneses et al. 2018. These studies guided the current study in terms of determining levels of intersemiotic relations (from simple to complex) by providing qualitative and quantitative data. These studies also enlightened the present study in terms of naming and classifying intersemiotic relations, and how to distinguish one form to another with characteristic aspects. The following titles will describe groups and categories of intersemiotic relations.

2.4.1 Monomodal representations

Monomodal representations include just written mode as shown in Figure 2. For instance, while Figure (2a) mentions what transparent and opaque matter are, and classifies matters according to transmission of light, the representation does not include any image in relation to the written text. In a similar vein, whereas the text at Figure (2b) tells about functions and properties of pancreas, it does not contain any image that refers to the written text.



(a) (b)

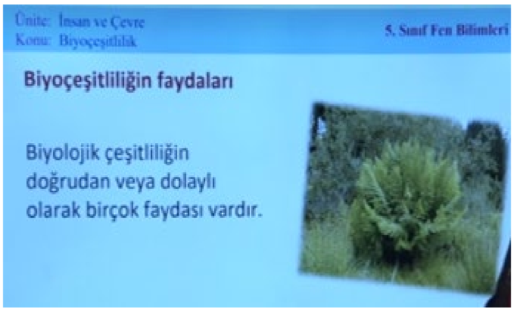
Figure 2. Examples of monomodal representations.

2.4.2 Ideational concurrence

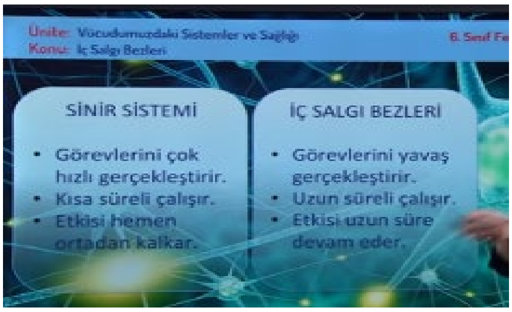
Ideational concurrence refers to ideational equivalence between image and text (co-variation or co-variate unity) or ideational meaning corresponds across semiotic modes. From an equivalence perspective, image and text have similar participant-process-phenomenon configuration (Gill, 2002). There is a correspondence between image and text regarding meaning (Unsworth, 2006b). Daly and Unsworth (2011, p. 62) defined it as "one mode elaborates on the meaning of another by further specifying or describing it while no new element is introduced by the written text or image". The concurrence is classified into four categories: 1) decorational, 2) exemplary, 3) representational, and 4) extension.

2.4.2.1 Decorational

It means image or text may not be integrated, or even referred to each other. Few meaningful links can be established in decorational relation, and do not encourage learners to understand science concepts. Image or text mirrors few aspects of each other, reflecting minimal information about themes. Images may not be integrated in the written mode or vice versa. In the decorational relation, the image has a trace amount of semantic correspondence with the text, or vice versa. Few or non-meaningful links can be established (Figure 3). For example, in Figure (3a), while the text indicates direct or indirect benefits of biodiversity, the image only shows a tree, that is, the image or text does not refer to each other. In a similar way, whereas the text at Figure (3b) is about comparison of the nervous system and the endocrine system, and properties of both systems, the image only reveals neurons that is the image only corresponds to the image of a concept in the nervous system.



(a)

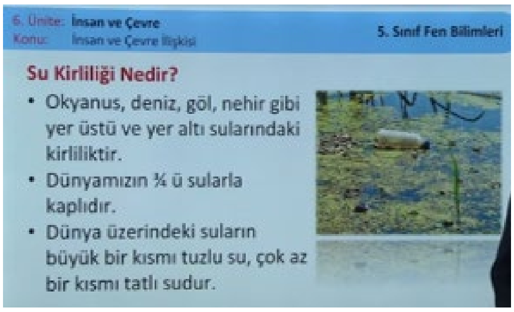


(b)

Figure 3. Examples of decorational multimodal representation.

2.4.2.2 Exemplary

In exemplary relation, the text is an example of image or vice versa. Image functions as an example or instance of what is in the text, or the text may include an example of what is depicted more generally in the image (Figure 4). For instance, while the text is about what water pollution is in Figure (4a), and the image shows an instance of water pollution. Likewise, the text at Figure (4b) mentions the endocrine system, and the image shows some examples of glands in this system.



(a)

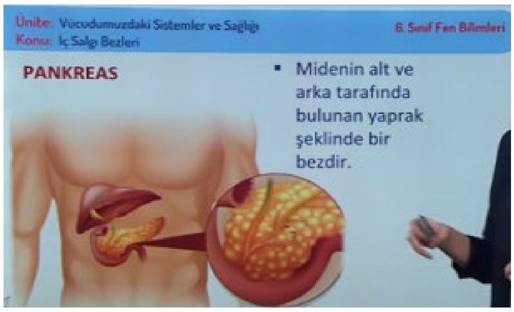
(b)

Figure 4. Examples of exemplary multimodal representations.

2.4.2.3 Representational

It means there is a correspondence between image and text in terms of redundancy of meaning. In other words, images mirror the information contained in the text. In the representational relation, the image mirrors the same meaning in the text, and there is a repetition of meaning (Figure 5). There is an exact correspondence regarding meaning between image and text. For example, Figure (5a), the text tells that full shadow occurs in the region where rays cannot reach, and the image corresponds to this meaning exactly. In Figure (5b), the text means that the pancreas is a leaf-shaped gland located at the bottom and back of the stomach, and the image transmits the same meaning.

(a)

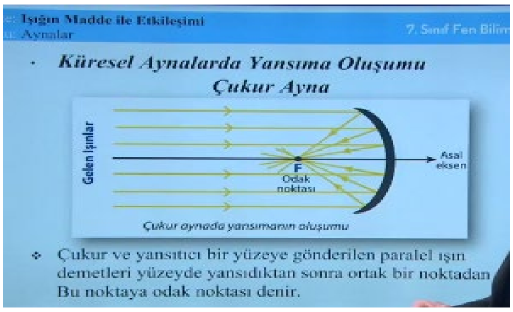


(b)

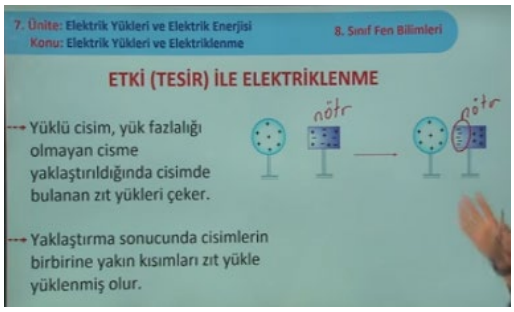
Figure 5. Examples of representational multimodal representations.

2.4.2.4 Exposition

It means to the re-description or re-identification of the image or the text in different mode considering the same level of generality. In the exposition type of relation, the text or the image re-expresses each other with alternative modes (Figure 6). For instance, in Figure (6a), while the text mentions how parallel light beams reflect in a concave mirror, the image re-configures the same meaning with symbols of ray and concave mirror. Likewise, in Figure (6b), whereas the text tells the statement of 'the approaching of a charged object to a neutral object result in acting of opposite charges to the different poles in the neutral object', the image reveals this situation with some figures in a sequential way.



(a)



(b)

Figure 6. Examples of exposition multimodal representations.

2.4.3 Ideational complementarity

Ideational complementarity refers to an image or text that extends the meaning of another by adding new and related information regarding how, when where or why in relation to each other (Martinec & Salway, 2005; Unsworth, 2014). Daly and Unsworth (2011, p. 63) identified it as "a new meaning is introduced by either the written text or image. It can be in the form of an extension". The complementarity is classified into four categories: 1) comparative, 2) organizational, 3) augmentation, and 4) interpretational.

2.4.3.1 Comparative

These relations provide learners to make comparisons and to understand similarities and differences between information presented by image and text. Comparative multimodal representations include two or more objects' dimensions in the same or different topics. Comparative relation enables students to comprehend similarities and differences between concepts (Figure 7). The study showed that there are no comparative representations used in 5th, 6th, and 8th grades' science classrooms. The following examples were taken from 7th grade's classroom. Figure (7a) and (7b) compare close and distance view of the object in the plane and concave mirrors respectively. While texts express the state of objects being far or near, the images help the reader to comprehend how views differ when objects are situated into two different positions.

(a)

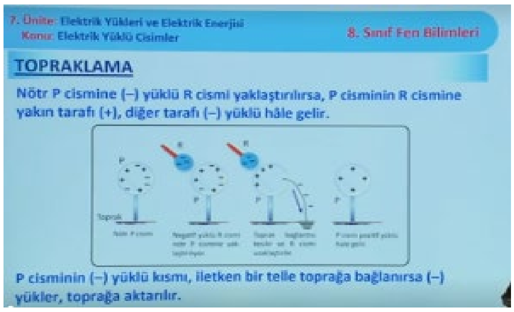
(b)

Figure 7. Examples of comparative multimodal representations.

2.4.3.2 Organizational

It refers to integrated image and text construct activity sequences and processes. Meanings are co-jointly distributed across text and image. Complementarity meanings (in activities and processes) are distributed across image and text (Chan & Unsworth, 2011; Daly & Unsworth, 2011) (Figure 8). Figure (8a) views the metamorphosis process of butterflies in 7th grade's science classroom. While the text expresses that some living things undergo morphological changes after hatching, and finally resemble the main living thing, the images show how these morphological changes occur. In this way, both image and text extend the meaning in the representation and share meaning load between each other. In another example, Figure (8b) demonstrates the plausible sequences of grounding in 8th grade. While the text describes what happens when a positive object approaches a neutral object and the negative part of the neutral object is connected to ground by a conductor, the image reveals which charge the object has as a result of this sequence of events. That is, all the meaning conveyed by the representation is shared between the text and the image mode, and these modes present a sequence of events.

(a)



(b)

Figure 8. Examples of organizational multimodal representations.

2.4.3.3 Ideational

These meanings made in multimodal text are extended in augmentation relations. Images enable supplementary ideational elements to those realized by the text or the text extending the meanings realized in the image (Chan, 2011; Daly & Unsworth, 2011). For instance, image augments meanings in the text by modelling to make it easier to visualize in mind. Augmentation relation enhances ideational meanings made in text (Figure 9). For example, at Figure (9a), the image expands the meaning of global warming text by symbols and signs of light reflection, light absorption, and temperature rise. While the text only includes the statement of 'global warming', the image extends this meaning by showing how this issue arises with radiation emitted by the warming earth and its return from the clouds. In Figure (9b), the image enhances the meaning of the text: 'nervous and endocrine systems should function in an organized manner so that other systems can work in harmony' by showing all systems as holding hands.

(a) (b)

Figure 9. Examples of augmentation multimodal representations.

2.4.3.4 Interpretational

These relations include image and text together demanding students to establish and understand the causal relationships provided in representations. It involves causality and generative descriptions of a phenomenon. Interpretational relation encourages students to think critically considering causality and generative descriptions of a phenomenon under investigation (Figure 10). In Figure (10a), interpretational representation guides students to comprehend causal relationships between insulin, glukagon, and blood sugar. While the text explains the statement of 'if the insulin hormone is not secreted enough, the sugar level in the blood increases and diabetes occurs', the image enables readers to comprehend causal relationship between insulin and diabetes with graphics. In another example, in Figure (10b), the multimodal representation encourages students to understand why spreads in the slowest gases and in the fastest solids sound. Whereas the text points out that sound is transmitted fastest in solids, the densest state of matter, and slowest in gases with the lowest density, the image allows readers to understand that there is a causal relationship between sound transmission and the particulate nature of solids and gases.

(a) (b)

Figure 10. Examples of interpretational multimodal representations.

Reliability and Validity of the Analytical Framework

Reliability of the analytical framework is defined by intra-rater and inter-rater reliability. For intra-rater reliability, the same researcher made observations in two distinct times (2 weeks long time gap). For inter-rater reliability, each of two researchers made observations and comprised the consistency among given categorical responses. Researchers observed and recorded concurrence and complementarity features of all image-text relations in multimodal representations in distinct times. We used Cohen's Kappa test to see consistency between observations (Cohen, 1960).

As shown in Table 1, there is moderate agreement between two measurements at different times in multimodal representations of environment and human and propagation of light topics. There is substantial agreement between two measurements in the subjects of biodiversity, light, sound, regulatory systems, mirrors, lens, growth in plants, electricity, charged substances, environmental science, and climate change in terms of intra-rater reliability. There is also perfect agreement between two measurements in the subjects of endocrine system, sound speed, and the subject of growth in terms of intra-rater reliability.

Table 1. Cohen's kappa results of 8th grade's multimodal representations.

Grade	Lessons	Intra-rater	Inter-rater
5th	Biodiversity	,785	,720
	Environment and Human	,550	,598
	Light	,750	,859
	Propagation of light	,538	,826
6th	Regulatory systems	,761	,761
	Endocrine system	,823	,762
	Sound	,648	,654
	Sound Speed	,846	,577
7th	Mirrors	,753	,831
	Growth	,813	,822
	Growth in Plants	,637	,656
	Lens	,724	,830
8th	Electricity	,758	,807
	Charged Substances	,766	,879
	Environmental Science	,840	,848
	Climate Change	,754	,616

As stated in Table 1, there is moderate agreement between two different researchers in the subject of sound speed. There is substantial agreement between two different researchers in the subjects of biodiversity and environment, regulatory systems, endocrine system, sound, growth in plants in terms of inter-rater reliability. There is also perfect agreement between researchers in the subjects of light, propagation of light, mirrors, growth, lens, electricity, charged substances, and environmental science in terms of inter-rater reliability.

Content validity of these analytical frameworks was realized by asking three pioneered researchers who study intersemiotic relations between image and text modes, and SF-MDA. Researchers indicated that the analytical framework is comprehensive and productive in identifying each choice in the system network.

3 Results

The present study investigated the number of representations used in all grades at first (as shown in Figure 11). These representations were determined by considering the criterion of dimension which refers to a distinctive aspect of the concept represented. That is, in order for a representation to be accepted as a unit of analysis, it is determined as a prerequisite that it describes the concept or one of its dimensions. In this context, 318 representations were identified totally in all grades. Results showed that the most frequent ones were used in eight grades (92). The number increased as parallel with the grade levels, except for the fifth grade.

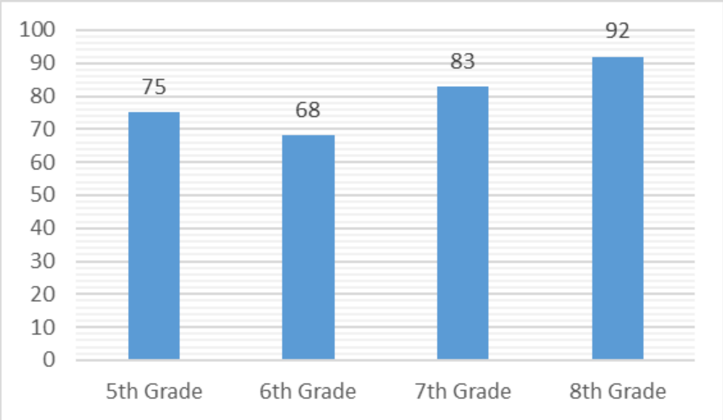


Figure 11. Number of representations used in each grade level.

Second, the researcher identified the types of intersemiotic relations between image and text in multimodal representations at all degrees. Figure 12 shows all dispersion, frequencies and percentages of image-text relation types. Results showed that the most prevalent intersemiotic relation used was the exemplary relation (44%). The next prevalent ones were decorational (11%) and representational (9%) relations sequentially in the concurrence category. The least prevalent ones were augmentation (4%), interpretational (4%), organizational (3%), and comparative (2%) relations sequentially in the complementary category. Moreover, the present study showed that there were no image-text relations in 20% of representations. They are called monomodal representations.

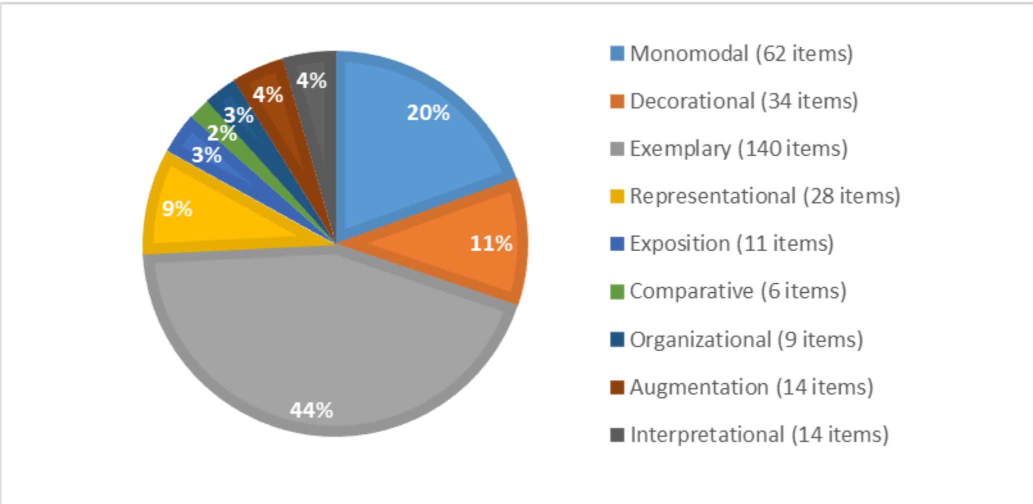


Figure 12. Number and frequencies of intersemiotic relations used in all grades.

As seen in Figure 13, the most frequent level used in all grades' multimodal representations is Level 1, then the latter one is Level 2. The usage number of Level 2 intersemiotic relations is nearly close to each other in 5th and 6th grades and increases as the grade level increases. Third level intersemiotic relations seem to be used most often in the seventh grade, and at least in sixth grade. Data shows that the usage number of third level intersemiotic relations in fifth grade is equal to eighth grade. There is a huge gap between the usage number of low level intersemiotic relations (Level 1 and 2) and high-level ones (Level 3 and 4) in all grades. There is no consistent increase or decrease in the use of high and low level intersemiotic relations in all grades. This issue can be interpreted as unintentional choice and use of these relations.

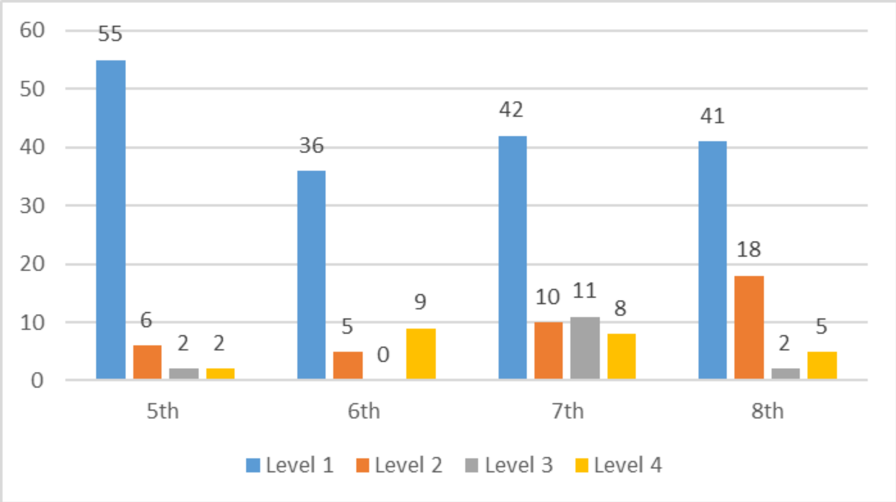


Figure 13. Intersemiotic relations levels with respect to grade levels.

As shown in Figure 14, types of intersemiotic relations have similar usage prevalence in different grades. For example, the most common image-text relation used in multimodal representations is exemplary in the concurrence category, then the second one is decorational. The usage of representational is nearly close to decorational ones, and there is no exposition relation both at 5th and 6th grades. Furthermore, the least ones at different grades also indicate similar results in the complementarity categories. For instance, there is no comparative and interpretational relations at 5th and 8th grades. There is an equal number of organizational relations at 5th and 8th grades. Likewise, there is an equal number of augmentation relations at 5th and 7th grades, and 6th and 8th grades. There is no comparative relation at 5th, 6th, and 8th grades. Data reveals that the usage prevalence of high levels of intersemiotic relations (complementarity ones) increases, as grade level increases from 5th to 7th. Findings also indicate that the usage frequency of upper level intersemiotic relations (representational and exposition) in the concurrence category increases in parallel with grade levels. The number of complementarity relations decreases at fifth grade and reaches the highest level at seventh grade. There is a huge gap between the number of exemplary relations and other types of intersemiotic relations at all grades. Moreover, the gap between the number of concurrence and complementary relation types is large at all grades.

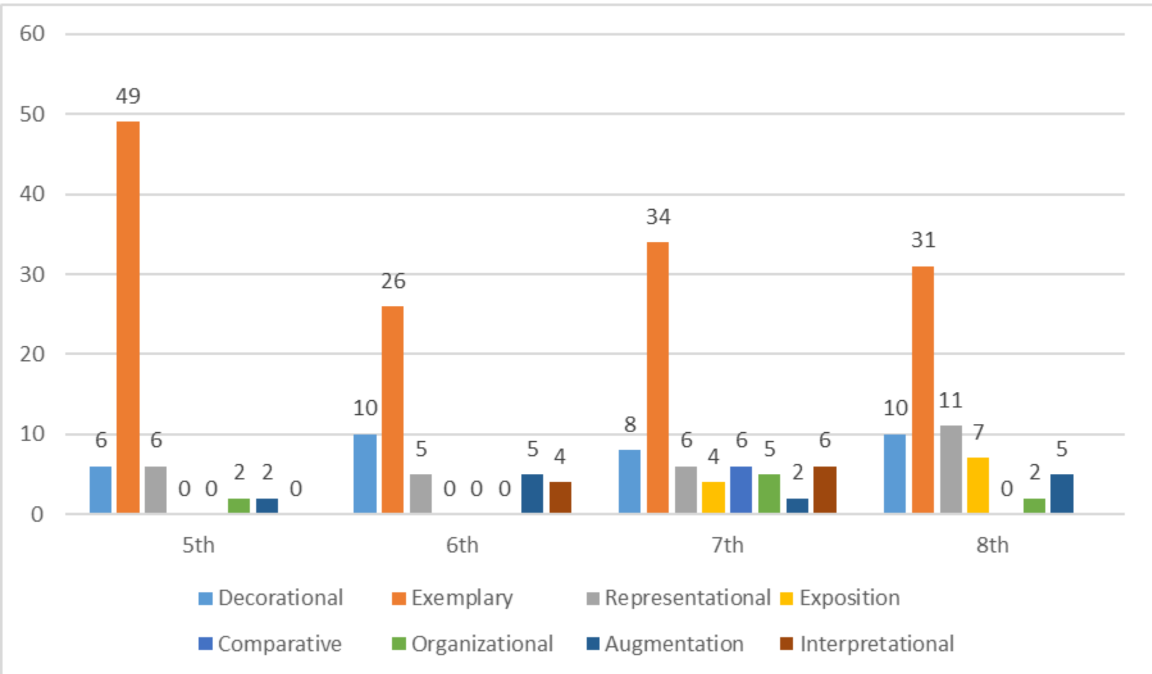


Figure 14. Intersemiotic relations with respect to grade levels.

4 Discussion and Conclusion

Digital world has enabled different types of representations to be constructed in various ways (Kress, 2005; Bezemer & Kress, 2008). These consist of several modes and their combinations (image, language, sound, and gesture) together, and so they are called multimodal representations. In this context, scientific texts are also multimodal and involve rearrangement in the critical constellation of modes of representation and media of dissemination (Murcia, 2014). Shortly, the digital learning environment provides teachers to use and construct multimodal representations in distinct ways, however relatively less research has been made to how teachers realize the difficulty level of these texts with respect to cognitive level of their students (Oliveira et al., 2014). And the studies showed that there is a need to comprehend how teachers experience a multimodally rich environment while teaching (Søndergaard & Hasse, 2012; Andersen & Munksby, 2018). Due to these reasons, the present study seeks to investigate how the difficulty level of multimodal representations is realized by science teachers of gifted students with respect to intersemiotic relations in science education of gifted students. So, the study demands answers to the following research questions.

The former question is about investigating what types of intersemiotic relations used in science education of gifted students. Results showed that teachers generally use multimodal representations including images and texts in different categories and relationships. These texts generally include primitive forms of multimodal representations that belong to the concurrence category. Moreover, the present study showed that there were no image-text relations in 20 percentage of representations. The number of advanced forms of multimodal representations is minimal. It seems that such texts are far from meeting the teaching and learning needs of gifted students. These types of texts do not offer any challenge for gifted students, and just include over repetition of scientific explanations. These representations do not consist of detailed explanations which encourage gifted students to make interpretations of these texts in different ways, so these texts do not promote gifted students' creativity, individuality, and independence. The findings revealed the complexity of this pedagogical activity. Previous studies have also supported these findings above that teachers were not aware of designing multimodal representations in terms of difficulty patterns (Keles, 2016; Prain & Waldrip, 2006; Tang, 2016; Tippett, 2011; Tytler, 2007). Likewise, teachers had experienced difficulties in using and designing multimodal representations (Yeo & Nielsen, 2020). They were not aware of semiotic affordances or limitations of multimodal representations (Eilam & Gilbert, 2014). They need to be aware of what or which a mode is best apt for realising conceptual meanings, and how to orchestrate different modes for the necessary pedagogical support with regard to cognitive level of their students (Yeo et al., 2021), because it is apparent that, the more the teacher is semiotically aware, the more s/he is able to use or design more coherent and challenging multimodal representations. Moreover, if the teachers provide opportunities with students to communicate in multimodal environment, this improves students' knowledge of the discourse of science (Wu et al., 2019). Being aware of multiple modes reinforces role of teachers as the explainer in the instruction process (Pantidos, 2017).

The issue largely stems from lack of pre-service and in-service teacher training programmes about designing and presenting multimodal representations (Kress, 2005; Yeo & Nielsen, 2020). Thus, the present study's results also showed that it is crucial to arrange teacher training programmes or professional development programmes in order to equip teachers with the necessary knowledge and skills about multimodal representations, since these primitive forms used by teachers couldn't reinforce students to construct meaningful internal/mental representations, so do not result in meaning making, learning, and creativity (Cheng et al., 2020; Nielsen et al., 2020; Waldrip et al., 2010). In a similar vein, as different levels of image-text relationships activate different mental processes, teachers should be trained to design advanced levels of multimodal representations which encourage gifted students' creativity and their teaching and learning process (Schneider & McGrew, 2013; Tytler et al., 2020).

The second question posed by the research is to examine the difficulty level of multimodal representations used in each classroom and how this situation changes according to grade levels. Results clearly showed that the difficulty level of intersemiotic relations and the distribution of types of these relations were nearly close to each other in all grades. The most often used ones were situated into Level 1 and Level 2, that is called low level of intersemiotic relations. There was no consistent increase or decrease in the use of high and low level intersemiotic relations regarding grade levels. That is, data revealed that designing and choosing of different multimodal representations is not intentional, it is just arbitrary (McDermott & Hand, 2010). There was no intentional choice about image-text relations regarding specific subject, grade levels, and ages. While the researcher, simply, expects a gradual increase from concurrent ones to complementarity representations as grade level increases, they did not obtain plausible output about this expectation. This data asserted that teachers did not consider cognitive levels of different grades. Using non-text, exemplary, decorational, and representative representations (84%) dominantly indicated that designers did not so much think upon relations between modes in their pedagogical discourse. These types of relations did not present challenging teaching materials for gifted students. This showed that teachers were not aware of how different types of intersemiotic relations impact attention, interest, learning, and creativity of gifted students. Data also revealed that teachers were adequate in how images and texts might say the same thing (concurrently), however they were not capable of embedding how images might say something that cannot be said with text or vice versa (Stieff, 2011). All these incompetencies may have originated from the following reasons: (1) teachers lack adequate experiences about embedding image and text (Mayer & Moreno, 2003), (2) they have not awareness about functional and formal patterns of modes (Ainsworth, 2006).

As a conclusion, since well-orchestrated representations improve learning, meaning making, creativity, decrease cognitive load, and support limited capacity of working memory, teachers need to learn the grammar of the image-text relations rather than using them arbitrarily (McDermott & Hand, 2013; Kind et al., 2017). Hence, teachers should be representationally competent regarding intersemiotic relations. That is, teachers (pre or in services) must understand the nature of multimodal representations (Shannon, 2014). They must know how to select, design and assess multimodal representations in order to meet teaching and learning of students, so there is a strong corresponding need to build these skills in teachers (Lim, 2019). As indicated by Patron, et al. (2017), teachers need (1) a semiotic awareness, (2) representational competence for design, and (3) use of meaning making affordances. Teachers should be aware of how to construct multimodal representations between modes and how to combine various types of images with texts (Xu et al., 2020). It is apparent that teachers should be equipped with the abilities of being aware of, identifying, and selecting best suited multimodal representations regarding the subject in focus.

5 Implications

The present study offers an image-text relations analysis framework for researchers and teachers. The framework can guide researchers to identify teachers' pedagogical strategies by comprehending the nature of intersemiotic relations (Kress & Bezemer, 2009). In this way, they can examine the multimodal nature of communication in the classroom and can make research about the impacts of different pre-service and in-service multimodal training programs on teachers' representational competence skills. Such a framework can also be used by instructors to understand intersemiotic mechanisms between images and texts, and it enables them to make meaningful choices while constructing knowledge (Tang, 2016). Also, understanding the concurrent and complementary relationship between modes can provide teachers to engage, enthuse, educate the students, and realize disciplinary specific classroom discourse more effectively (Prain & Waldrip, 2006). The framework can provide teachers how to use multimodal representations as epistemic objects (Evagorou et al., 2015). Moreover, the framework can be used as guidance for identifying schematic structures of scientific explanations (Qiuping, 2019). It can enable us to understand how teachers use semiotic resources while enhancing their students' learning opportunities. It can inform the planning, design, and improvement of teaching materials and activities from a multisemiotic perspective. Shanahan (2013) argued how important it is for teachers to know and design these metafunctions. Findings from this study can shed light on issues such as how to efficiently use multimodal resources, and how and in what ways modes can be integrated in order to rich learning environments. The framework can also support –directly- improvement of teachers' multimodal literacy and as well as –indirectly- students' (Danielsson & Selander, 2016; Wanselin et al., 2022).

6 Conflict of Interest

"The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest".

7 Author Contributions

Conceptualization, Gül. M.D. and Costu. B.; methodology, Gül. M.D.; data curation, Gül. M.D.; writing—original draft preparation, Gül. M.D.; review and editing, Costu. B.; visualization, Gül. M.D.; supervision, Costu. B. All authors have read and agreed to the published version of the manuscript.

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