**KURAM VE UYGULAMADA EĞİTİM BİLİMLERİ** EDUCATIONAL SCIENCES: THEORY & PRACTICE

**Received:** October 23, 2013
**Revision received:** April 20, 2015
**Accepted:** September2, 2015
**OnlineFirst:** February 15, 2016



**ISSN** 1303-0485 **eISSN** 2148-7561
www.estp.com.tr
**DOI** 10.12738/estp.2016.1.0054 • February 2016 • 16(1) • 109-126

***Original Article***

# Modal Representations and their Role in the Learning Process: A Theoretical and Pragmatic Analysis

Murat Gunel[1]
*TED University*

Funda Yesildag-Hasancebi[2]
*Giresun University*

**Abstract**

In the construction and sharing of scientific knowledge, modal representations such as text, graphics, pictures, and mathematical expressions are commonly used. Due to the increasing importance of their role in the production and communication of science, modal representations have become a topic of growing interest in science education research in recent years. Resulting from this research are indications that students who can mentally identify modal representations, understand their function in communication, and make transitions between different representation modes learn scientific concepts more easily and permanently. Furthermore, when modal representations are integrated into writing-to-learn activities, they serve as an alternative method of teaching and measurement of assessment for teachers as well as a learning tool that activates students' cognitive abilities. In this study, the concept of representation, the framework of which has not yet been clearly established in the related literature in Turkey, and the characteristics of modal representations have been addressed together. Furthermore, their role in science education and writing-to-learn activities has been explored by considering their theoretical and pragmatic dimensions.

**Keywords**

Modal representations • Science Education • Writing-to-learn • Multi-media learning • Science teaching

* A Turkish version of the article can be obtained from the corresponding author.

1 Correspondence to: Murat Gunel (PhD), Department of Primary Education, TED University, Ziya Gokalp Cad. No: 48, Kolej, Ankara Turkey. Email: murat.gunel@tedu.edu.tr

2 Department of Science Education, Giresun University, Turkey. Email: funda.hasancebi@giresun.edu.tr

**Citation:** Gunel, M., & Yesildag-Hasancebi, F. (2016). Modal representations and their role in the learning process: A theoretical and pragmatic analysis. *Educational Sciences: Theory & Practice, 16,* 109-126.

Recent developments in science and technology which resulted in improvements in learning and teaching environments have brought the concept of multimedia to the forefront. Multimedia is defined as a combination of multiple technical resources with the aim of representing new technologies and information (Schnotz & Lowe, 2003). Simply put, multimedia represents an environment that appeals to the senses and hence has an important role in the learning-teaching process (Akkoyunlu & Yılmaz, 2005). Akkoyunlu and Yılmaz (2005) elaborated on this concept, suggesting that it improves student motivation and achievement by addressing more than one sensory organ through the use of various resources. In this context, Mayer (2003) suggested that using various technologies does not change the nature of how the human mind works; however, when instructional technologies are intelligently designed, they can work as a powerful tool for human cognition. Furthermore, according to Mayer, students can learn more easily by building mental representations from the pictures and words presented to them in multimedia learning environments.

Akkoyunlu and Yılmaz (2005) consider instructional technologies as the primary resources of multimedia learning environments and have classified them according to the sensory organs they address as follows: visual media such as books, whiteboards, pictures, charts, graphs, real objects, or models; audio media such as radio, records, cassettes, and audio tapes; and audiovisual media which includes films, animations, television, and video. According to Schnotz and Lowe (2003), multimedia resources can be analyzed in three different levels: technical, such as computers and networks; sensory, which indicates the stimulation of senses using visual or auditory modality; and semiotic, which refers to representational formats such as text, pictures, and audio. Investigating the literature on teaching and learning based on these levels, Schnotz and Lowe concluded that the majority of research in this field has focused on the technical level rather than the sensory or semiotic. Therefore, the impact of the semiotic and sensory levels on learning is still open to investigation.

The main goal of multimedia learning is to initiate deep learning in students through the use of multimedia messages involving words, symbolic representations, and pictures rather than a mode of communication based solely on words (Mayer, 2003). Mayer further explained that the factors that initiate learning are not just media environments but also the contribution of media environments to cognitive processing. In other words, multimedia learning environments provide individuals with representations of various forms and alternative learning methods (Schnotz & Bannert, 2003). In these representations, the target content is presented using modes.

Modes consist of representations such as pictures, graphs, and diagrams. Representations can be composed of a single mode or multimode involving more than one mode. Representations play a role in the cognitive structure of an individual and how it selects and organizes information, examines symbolic structures, and maps exemplary structures (Schnotz & Bannert, 2003). In addition, a variety of representations in visual and auditory dimensions enriches cognitive processes and triggers the processes of selection, organization, and integration, which in turn promotes meaningful learning (Mayer, 2003). The effective use of representations for predefined purposes also provides cognitive diversity and depth to the learning and thinking processes. Thus, it has a potential to offer significant benefits that help achieve the desired outcomes (Gero & Reffat, 1997). In parallel with the growing interest in representations and their relationship to learning in various fields, research in science education in this particular area has also increased both nationally and internationally.

The research available in Turkey has focused on the impact of representations on learning the subjects of science, physics, and chemistry in primary, secondary, and university schools (Yesildag & Gunel, 2009; Koç, Kıngır, & Günel, 2012); analyzing the transitions between different modes of representations (Çelik & Sağlam-Arslan, 2012); and identifying the modal representations used in educational research (Demirbağ & Günel, 2014). In the international literature, on the other hand, the relationship between learning and the use of modal representations has been examined in detail, taking both theoretical and pedagogical aspects into consideration (Choi, 2008; Hand & Choi, 2010; McDermott, 2009).

This study will examine in detail representations, modes, and structures and their relationship with learning.

## Representations and their Function in the Learning Process

Gero and Reffat (1997) defined representations to include objects and relationships that establish meaningful links between one object or phenomenon and another. Moreover, representations can govern the behavior, transformation, and creation of objects and phenomena. Wu and Puntambekar (2012) suggested that the term representation can be used to depict a mental structure in the form of mental models and cognitive structures. Using more concrete terms, Tang, Delgado, and Moje (2014) compared representations to artifacts which can take the form of simulations, graphs, diagrams, written text, oral expressions, and analogies to symbolize concepts and claims in science (force, energy, chemical equilibrium). A review of the research in the fields of language and education shows that representation is defined as a type of transformation or change of information obtained through the conceptualization, visualization, or concretization of an item in a certain format or mode. Based on this definition, representations can be concluded to have emerged as an integral part of the language of science (Tang et al., 2014).

Representations can be classified by different characteristics such as sensory channels (auditory/visual), modalities (text/graphs), levels of abstraction (concrete/

abstract), dimensionality (one or multiple dimensions), or types of presented information, such as qualitative or quantitative (Wu, Lin, & Hsu, 2013). Various classifications, levels, and dimensions of representations have been developed in the literature on education; only a few have been used in combination, however (Wu & Puntambekar, 2012). Furthermore, no consensus on the classification of representations in science education research has been reached, as discussed by these researchers. Moreover, the universal theoretical content of representations and modes should be discussed as a whole, and how this content is reflected in the learning environment should be evaluated. Therefore, this paper will not only focus on the review and discussion of the theoretical background of modes and representations, but also on the functions of representations in the learning process. Furthermore, a widely cited classification of representation developed by Schnotz and Bannert (2003), which has been integrated into learning processes, has particular importance for the practical consideration of representations in learning.

Schnotz and Bannert (2003) categorized representations into two groups: descriptive and depictive. These researchers defined descriptive representations as spoken or written texts, mathematical equations, or logical phrases consisting of symbols to describe an object. Depictive representations, on the other hand, present relational information either in a static form (as in pictures, schemas, or diagrams) or in an animated form (such as visualizations including maps and graphics). Schnotz (2002) considered both descriptive (texts and mathematical representations) and depictive representations (visual displays) as external representations. These two types of external representations serve different purposes. According to Schnotz (2002), while descriptive representations indicate a general deficiency or discrimination, depictive representations can display a special deficiency and describe these discriminations through consecutive pictures. Schnotz (2002) suggested that descriptive representations, despite the research in recent years that has focused intensely on the relationship between learning and depictive representations, in fact have a higher representational power; thus they would be more effective in fostering learning. Therefore, exploring the functions of descriptive representations (text, mathematical formulae, or equations) and their impact on student learning can provide a better understanding of the related phenomena and concepts as well as their relationship. This type of investigation requires a detailed analysis of the use of descriptive and complementary representations in textbooks and reading and writing activities, as well as an exploration of teachers' understanding of the function of these representations in the teaching process. A similar classification to Schnotz's can be seen in the representational classification of Wu and Puntambekar (2012). Wu and Puntambekar were inspired in their classification of representations by Johnstone (1982; 1993), who had identified different levels in chemistry (macro, micro, and symbolic levels), an idea that was then extended to the area of physics by Lemke (1998), then to biology education by Tsui (2003). Guided by these studies, Wu and Puntambekar classified representations as verbal-textual (linguistic symbols and words), symbolic-mathematical (sign symbols and mathematical equations), visual and graphical (graphics, pictures, animations, and videos) and actional-operational (demonstrations, physical models, and gestural expressions). Furthermore, the authors suggested that this classification reflects the multidimensionality of external representations in science and includes different systems of symbols.

The international research in the area of education has underlined the importance of external representations in supporting learning and teaching processes (Schnotz & Lowe, 2003; Wu & Puntambekar, 2012). Schnotz (2002) suggested that external representations can only be understood when an observer or reader converts the content shown in a picture or described in a text into mental representations. In other words, although modes generally describe the content or phenomena, perception and knowledge are actually constructed individually based on interactions within the learner's mental representation. Schnotz and Lowe (2003) focused on the complex interactions that take place in the internal mental representations of students exposed to external representations and instructional technologies. Considering that textbooks, teacher presentations, student course notes, internet resources, and all other information sources are externally represented forms of information, the degree of proximity to the relationship between these external representations and students' internal representations can be a criterion for learning. Similarly, a number of studies reported that such interactions help with learning complex new ideas and increase students' learning performance when used effectively (Ainsworth, 2006). Ainsworth (1999, pp. 146-147) identified the following three basic roles of representations that can be effective in pedagogy: (*i*) complementary (to initiate cognitive processes over a wide area and a function of representing or complementing phenomenon and information in different ways), (*ii*) stimulating interpretation (encourage learners to interpret the relationships between different representations and information with certain combinations of representations or different representations describing a single event or phenomena), (*iii*) constructing deeper understanding with the condition of using various representations of a single case.

Desired educational outcomes can be achieved more easily in learning environments where representations are consciously constructed by teachers either as instructional or learning materials for students (to complement, stimulate interpretation, or construct deeper understanding). The emerging idea that representations support the learning of new complexities and enhance students' learning performance has increased the number of studies and implementations in the fields of educational technologies and student literacy abilities (Norris & Phillips, 2003; Pineda & Garza, 2000). A prominent research topic in these fields is the investigation of the relationship between learning and the use of multiple representations (Ainsworth, 2006).

In recent years, the use of a combination of representations together has been suggested to instill a better understanding of an event or phenomenon and promotes their function in learning and understanding (Schnotz & Lowe, 2003). Gero and Reffat (1997) underlined the importance of using various representations since they offer additional advantages when combined. Similarly, Ainsworth (1999) considered the use of multiple representations to be an appropriate approach for capturing the learner's interest. In a more recent study, Ainsworth (2006) stated that most educational theories focus on the importance of multiple representations. In addition, the increase of multimedia learning environments over the last two decades has expanded the use of combined representations involving different modes such as diagrams, tables, texts, graphs, and animations. In the related literature involving the use of more than one representation, two concepts stand out: multiple representations and multi-modal representations.

Multiple representations mean the expression or display of the same concept in different representational forms (Prain & Waldrip, 2006). Research in this field has mostly examined the impact of more than one representation of the same concept or phenomenon on student understanding (Ainsworth, 2006; Tang et al., 2014). Research on multi-modal representations, particularly in science education, has focused on the relationship between science learning and the synchronous use of modes within or between representations (Airey & Linder, 2009; Lemke, 1998; Mursia, 2010). Multi-modal representations combine various modes (modalities) such as language, symbols, and depictions in order to describe concepts or phenomena. It is the process of expressing appropriate modes with appropriate concepts rather than describing the same concept or phenomena with different modes (Prain & Waldrip, 2006). Research on multi-modal representations considers the local use of various modes depending on the concept or phenomenon and how students combine the different parts of a representation (Tang et al., 2014). Research in this field has contributed to the learning process by describing different concepts and sub-concepts using various modes depending on their availability. Although multiple representations and multi-modal representations are different concepts, both terms have been used interchangeably in the literature (McDermott & Hand, 2013). The current paper will present modal representations and their use in the learning process.

## Learning with Modal Representations

Modes are displays (pictures, graphs, text, tables, diagrams, or animations) used to describe information. Since each mode has its own content and function, it can be used to present information or phenomenon in various ways. Furthermore, modes in representations have different strengths and weaknesses in terms of accuracy, clarity, and associative meaning. Ainsworth (2006) supported the idea that the same information can be described using various representations with different content. For instance, a text and a picture can be used together to effectively present the situation of a problem, while a diagram can be used to express qualitative data, and mathematical expressions and graphs to express quantitative information. Considering the impact of this principle on learning, one can infer that individuals who use modal representations in communication (reading or writing) easily contextualize the content to be communicated semiotically. In learning environments, students can develop a deeper understanding of a concept when they know about the properties of individual representations; this can also be beneficial in communication (Ainsworth & Van Labeke, 2004). Multiple verbal, graphical, and numerical modes provide learners with opportunities to revise the subject or explore it from a different perspective (creating new semantic networks), which then supports learning (Waldrip, Prain, & Carolan, 2006).

The use of modal representations consisting of two or more modes and transferring between them brings many advantages to learning. Prain and Waldrip (2006) suggested that students who recognize the relations between different modes perform better in conceptual learning than those who do not. Moreover, the conceptual development of students who can correlate various modes differs from those that cannot. Similarly, Ainsworth and Van Labeke (2004) suggested that the transfer of modes helps students build abstractions, which then can support the construction of deeper understanding and promote conceptual learning. Günel, Atila, and Büyükkasap (2009), and Airey and Linder (2009) stated that in current educational programs, students do not learn the function of modes and have difficulty in transferring modes; however, these researchers underlined the importance of encouraging students to use modal representations in terms of developing conceptual learning and increasing academic achievement.

The use of modal representations in constructing and sharing scientific knowledge also increases the quality of students' arguments, such as for establishing conceptual relations between a question, claim, and evidence (Choi, 2008; Demirbağ & Günel, 2014; Hand & Choi, 2010). Demirbağ and Günel argued that students educated in modal representations construct better quality arguments. These researchers suggested that developments in student perceptions towards modal representations contribute to improving related abilities, establishing effective relations between data, thinking multi-dimensionally, and drawing conclusions based on data and observations. Similarly, Mursia (2010) stated that students need to understand the modal representations of scientific concepts and be able to transfer them in order to learn the nature of scientific knowledge. These discussions indicate that students require specific exercises that allow them to use modes to the extent that they can achieve "knowing" within a field of science (Ford, 2007). Prain and Waldrip (2006) summarized the discussion on science education given above as the need for students to understand different modal representations and make relations between them in order to learn how to think and behave scientifically.

## The Use of Modal Representations as a Learning Tool in Science Education

While examining representations in science education, Klein, Lenoir, and Gumbrech (2003) deemed modal representations to be "paper tools" used by scientists for performing science and generating scientific knowledge. Waldrip et al. (2006), while evaluating the relationship between modal representations and science education, suggested that meaningful science learning depends on representing scientific reasons and findings, then interpreting the represented information. In other words, to conceptualize scientific concepts or content, the semiotic systems that are applied in performing and transforming science should be well understood (Lemke, 1998). At this point, the significance of modal representations as an important part of semiotic systems should not be overlooked (Yesildag & Gunel, 2009). Consequently, as the keystones of both understanding the nature of scientific knowledge and conceptualizing scientific content, representations and their functions in particular have become a topic of growing interest among many researchers in science education (Bennett, 2011; Demirbağ & Günel, 2014).

Both studies in Turkey and internationally agree that scientific practices should be constructed with consideration of the verbal, pictorial, graphical, and mathematical representations of similar concepts and phenomena (Gunel, Hand, & Gunduz, 2006; Prain & Waldrip, 2006). In addition, there is consensus among researchers on the need to provide students with an understanding of the use and development of various modes in the representation and expression of scientific concepts and phenomena rather than restricting them to specific modes (Prain & Waldrip, 2006). Similarly, Airey and Linder (2009) argued that students need opportunities to use tools, activities, and representations since they are the foundation of the construction process of science and scientific knowledge. The authors referred to what they called a "disciplinary discourse" consisting of the complex of three main elements: the tools, activities, and representations of any scientific discipline. They gave the examples of spoken and written language, mathematical expression, and animated pictures (pictures, graphs, and diagrams) for modes; research apparatus and measurement equipment for tools; and writing strategies and analytic routines for activities. Furthermore, Airey and Linder (2009) also suggested that learning experiences which use modes help students develop a disciplined way of knowing that involves both ontological and epistemological routines regarding knowledge. An improvement in a student's way of knowing can be associated with their development in scientific literacy as commonly discussed in national and international contexts (Emig, 1977; Milli Eğitim Bakanlığı [MEB], 2004; National Research Council [NRC], 1996; Prain & Hand, 1999; Yore, Bisanz, & Hand, 2003).

Studies focusing on the importance and necessity of modal representations show that scientists in the field of education mostly discuss this issue within the context of science literacy and writing-to-learn. For instance, Hand et al. (2003) stated that language skills are performed based on both planned and unplanned science literacies. Moreover, learning should focus not only on the development of social skills for literacy, communication, and collaboration, but also on improvements with visual, audio, behavioral, and digital modes. Similarly, Tytler, Prain, and Peterson (2007) suggested that students acquire deeper and more comprehensive knowledge when modal representations (including modes such as text, graphs, pictures, diagrams, lists, and mathematical expressions) are included in their writing-to-learn activities. As a key tool in the construction and transmission of scientific knowledge, modal representations constitute an important basis for written communication. Therefore, the most appropriate theoretical and pedagogic way for students to learn the structure and functions of modal representations is to engage in writing-to-learn activities where they can fully comprehend the targeted learning content and develop positive perceptions of scientific literacy.

## Modal Representations in Writing Activities

Writing is an important part of science; scientific literacy and language processes are necessary tools for undertaking science. Moreover, writing is an integral part of building complementary ideas, gaining understanding, and presenting investigations; it facilitates the transmission of scientific knowledge from generation to generation. According to Yore et al. (2003), writing is a construct of knowledge and a process by which the writer recalls understanding and forms scientific ideas and mental models. Writing-to-learn is an epistemological tool that fosters knowledge and understanding in learners, develops self-conceptions, and provides guidance for scientific literacy (Hand, Prain, Lawrence, & Yore, 1999). Moreover, rather than being a simple tool for representing information, writing is viewed as an interactive learning tool (technology) that incorporates students (Eming, 1977; Galbright 1999; Yore et al., 2003), and related activities are called writing-to-learn activities. A considerable amount of research has been conducted in this area.

Writing-to-learn activities provide students with rich cognitive activities in which they construct scientific knowledge and develop new understandings that require conceptual change (Gunel, Hand, & Gunduz, 2007; Hand et al., 1999; Mason & Boscolo, 2000). Furthermore, writing activities help students establish connections between daily and scientific language. With these activities, it is possible to change the language routines for concepts and explanations by expanding the cognitive structure, which would result in student learning (Hand Hohenshell, & Prain, 2004; Yesildag & Gunel, 2009). The use of these activities in science provides students with opportunities to connect prior knowledge to new information, investigate alternative ideas, discover new possibilities, and understand various concepts by integrating them into instruction and assessment (Hand, Prain, Lawrence, & Yore, 1999). Writing-to-learn not only helps students' science learning by developing their logical thinking, stimulating scientific reasoning, and improving individual understanding of scientific explanations, but it also develops students' scientific literacy. To achieve all these and meet the requirements of curriculum, representations should be included in course plans and made available for educational processes.

Both traditional writing activities, such as summary writing (taking notes of what the teacher says), and non-traditional creative writing activities involving the use of posters, brochures, letters or PowerPoint provide students with opportunities to use modal representations. This facilitates student learning of scientific subjects (Yeşildağ, Günel, & Büyükkasap, 2008) since an understanding of science requires the comprehension of the semiotic systems used in performing and transmitting science (Lemke, 1998). Since modal representations are an integral part of these semiotic systems, the modal representations used in writing activities are as significant as writing-to-learn activities (Yesildag & Gunel, 2009). Therefore, students need to understand modal representations, recognize their role in describing a phenomenon, and use them to acquire conceptual science learning. In order to meet these requirements and help students and teachers benefit from the advantages of using modal representations, the following pedagogical process stages have been identified by researchers for implementation at various levels of education and in different sub-fields of science (McDermott, 2009; Yesildag-Hasancebi & Gunel, 2013)

**Identifying modal representations.** This stage involves the process of identifying modal representations in written materials and determining the relationship between each representation. Students are asked to examine and evaluate the modal representations in written materials individually or in small groups to widen their perception of these representations.

**Identifying the role of modal representations in the construction of scientific concepts.** This stage helps students deepen their understanding concerning the use of modes in written texts. In this stage, students are expected to assess a different written text that includes scientific issues using a rubric. Rubrics aim to develop students' conceptual understanding of modes and provide them with the written and oral expression of the assessments. Annex 1 presents an example of a rubric.

**Preparing writing-to-learn activities using modal representations.** Students are required to prepare a letter, poster, brochure, or any other method of inventory for the studied unit using modal representations. The inventory is prepared with the intention that students will describe the subject to their peers or a younger audience. Students are required to consider the above-mentioned assessment criteria and bring modes that both accurately and effectively represent the subject.

The written products obtained at the end of these stages (letters, posters and brochures) can be used as an alternative assessment and measurement tool; therefore, this process can be considered as a performance task. Moreover, these products can be used in school newspapers, poster exhibitions, or debates among classes. They can serve as an observation and assessment tool for teachers, and as an instructive material for students to help them understand the impact and roles of various modal representations, helping them implement what they have learned in area-specific applications.

Activities involving the use of various modal representations help students develop conceptual understanding in science and provide teachers with an insight into the thinking processes of students. The interaction of students with representations also allows teachers to determine students' efficiency in using representations and the average level of their understanding (Tytler et al., 2007). While investigating teacher proficiencies, Gonzalez, Prain, and Waldrip (2003) drew attention to the need for teachers' professional development in the understanding and use of modal representations as a method of science teaching. The researchers suggested that the focus of professional development should be on understanding the nature of various modes and transferring between modes. In this context, it is of great importance that teachers receive professional development in the student learning process of the use of modal representations, covering similar training processes as the students (Prain & Waldrip, 2006).

Despite being an integral part of science education, modal representations are not given sufficient attention in pedagogical practices or research. Discussions on the role and function of modal representations in learning that incorporate both theoretical and pragmatic aspects can make significant contributions to science learning.

## Discussion and Conclusion

The use of modal representations in science learning helps the learner understand different modes, transfer between modes, and coordinate the use of these modes in the represented scientific information, enhancing effective learning (Yeşildağ et al., 2008). In the process of constructing scientific knowledge, when students are provided opportunities to actively engage in using modes, they learn the topic to a greater extent more easily (Airey & Linder, 2009). Each modal representation has its own features with different strengths and weaknesses in terms of clarity and evocation, thus, they can meet the diverse needs of all learners. Furthermore, consideration of the features and functions of representations will support the process of comprehension and making associations between scientific concepts and phenomena (Airey & Linder, 2009; Lemke, 1998; Prain & Waldrip, 2006). The effective use of modal representations can provide cognitive diversity and depth in the thinking and learning processes. Furthermore, it contributes to the construction of abstract terms, developing deeper understanding and conceptual learning in science and academic achievement (Ainsworth & Van Labeke, 2004; Airey & Linder, 2009; Prain & Waldrip, 2006). Through their experience with modal representations, students can learn how to construct high-quality arguments, generate claims, and support these claims with evidence using inquiry-based approaches such as argument-based science education, learning cycle, or 5E instructional models (Choi, 2008; Demirbağ & Günel, 2014; Hand & Choi, 2010).

Using a combination of several representations further enhances the learner's representational skills and results in the learning process being more effective (Kohl & Finkelstein, 2006). However, when the educational process regarding the use of modal representations is not properly planned, students cannot benefit from these advantages (Waldrip et al., 2006). Therefore, students' ability to acquire knowledge using a scientific approach and to engage in conceptual learning is associated with their experience in identifying and implementing these modes. This should be taken into consideration in future educational plans.

As essential components of the education process, both students and teachers use modal representations. It is vital to use modal representations in situations according to their roles and functions, as well as to produce combinations of modes. Although a mode represents a meaning or phenomenon by itself, it only makes sense when individuals cognitively interact with the representations. The degree of proximity between the mental construction of individual internal representations and the presentation of external representations from outside of the learning environment can be a criterion for learning. Additionally, the ability of a student to recognize the more effective mode can reduce potential learning difficulties (Günel et. al., 2009). In this regard, teacher awareness on these issues and the construction of a learning environment which considers these will have positive results in the teaching process (Çelik & Sağlam-Arslan, 2012). Teacher recognition of the basic roles of representations (complementary, stimulating interpretation, and constructing deeper understanding) and effective integration into the teaching process are an important step towards achieving the expected outcomes in education. In this process, since modal representations constitute a major part of written communications, writing activities are the most appropriate resource for teachers to use with students in order for them to understand the structure and function of modal representations and how to use them (McDermott & Hand, 2013; Yeşildağ et al., 2008).

Similar to modal representations, writing activities are common practice in learning and teaching processes. Although writing activities are unique learning tools in science and other disciplines (Eming, 1977; Galbright, 1999; Yore et al., 2003), in Turkey's education system, they are often perceived as the practice of taking notes from what the teacher says (Biber, 2012). However, when used effectively, writing-to-learn activities contribute intensely to individual reasoning and the construction of scientific knowledge, and they establish a connection between daily and scientific language. In addition, they provide students with opportunities to recall prior knowledge, integrate new information into prior knowledge, and develop a holistic understanding of various concepts (Hand et al., 1999; Hand et al., 2004; Mason & Boscolo, 2000; Günel et al., 2009). Providing more opportunities than reading and speaking, writing is an effective, rich, and multifunctional tool for practical applications of modal representations.

Strengthening teacher perceptions toward the use of modal representations and the necessity of integrating them into writing activities will contribute to the learning process. However, considering the level of academic studies and curriculum development, Turkey is at the very beginning of this integration process. As reported by Biber (2012), the majority of science teachers in Turkey are far from using writing-to-learn activities and understanding the function of modal representations. The curriculum designed by MEB does not involve writing as a learning and communication tool. Moreover, the results of placement exams throughout the country indicate that in the current education system, 80% of the students have not developed the required writing skills (Eğitim Araştırma ve Geliştirme Dairesi Başkanlığı, 2011). The education system has been exposed to rapid political and social changes without the support of research findings, and there is a great need to present modern practices and their outcomes to policy makers and the public. In this context, the issues described above suggest that small changes to the education system in Turkey can produce significant results. Lastly, modal representations incorporate disciplines such as science, science education, linguistics, and neuroscience; with such a high research potential, they have the power to create interdisciplinary research synergy, which is much needed in Turkey.

## References

Ainsworth, S. (1999). The functions of multiple representations. *Computer & Education*, *33,* 131–152.

Ainsworth, S. (2006). DeFT: A conceptual framework for considering learning with multiple representations. *Learning and Instruction*, *16,* 183–198.

Ainsworth, S., & Van Labeke, N. (2004). Multiple forms of dynamic representation. *Learning and Instruction*, *14*, 241–255.

Airey, J., & Linder, C. (2009). A disciplinary discourse perspective on university science learning: Achieving fluency in a critical constellation of modes. *Journal of Research in Science Teaching*, *46*(1), 27–49.

Akkoyunlu B. ve Yılmaz M. (2005). Türetimci çoklu ortam öğrenme kuramı [Generative theory of multimedia learning]. *Hacettepe* Üniversitesi *Eğitim Fakültesi Dergisi*, *28*, 9-18.

Bennett, W. D. (2011). *Multimodal representation contributes to the complex development of science literacy in a college biology class* (Doctoral dissertation). Retrieved from http://ir.uiowa.edu/etd/1203/

Biber, B. (2012). *İlköğretim fen ve teknoloji öğretmenlerinin yazmaya dair algıları ve eğitim öğretim ortamında öğrenme amaçlı yazma aktivitelerini sınıf ortamında uygulama düzeyleri* [Science teachers? perceptions toward writing and levels of writing-to-learn implementations] (Master thesis, Ataturk University, Erzurum, Turkey). Retrieved from https://tez.yok.gov.tr/UlusalTezMerkezi/

Choi, A. (2008*). A study of student written argument using the science writing heuristic approach in inquiry–based freshman general chemistry laboratory classes* (Doctoral dissertation). Available from ProOuest Dissertations and Theses database. (UMI No. AAI3323405)

Çelik, D. & Sağlam-Arslan, S. (2012). Öğretmen adaylarının çoklu gösterimleri kullanma becerilerinin analizi [The analysis of teacher candidates' translating skills in multiple representations]. *İlköğretim Online, 11*(1), 239-250.

Demirbağ, M., & Günel, M. (2014). Argümantasyon Tabanlı fen eğitimi sürecine modsal betimleme entegrasyonunun akademik başarı, argüman kurma ve yazma becerilerine etkisi [Integrating Argument-Based Science Inquiry with Modal Representations: Impact on Science Achievement, Argumentation, and Writing Skills]. *Kuram ve Uygulamada Eğitim Bilimleri, 14,* 373-392.

Eğitim Araştırma ve Geliştirme Dairesi Başkanlığı (2011). *MEB 21. yy* öğrenci *profili* [The characteristics of a 21st century student]. Ankara, Turkey: Milli Eğitim Basımevi.

Emig, J. (1977). Writing as a mode of learning. *College Composition and Communication*, *28,* 122–128.

Ford, M. (2007). Disciplinary authority and accountability in scientific practice and learning. *Science Education*, *92*, 404–423.

Galbraith, D. (1999). Writing as a knowledge–constituting process. In D. Galbraith & M. Torrance (Eds.), *Knowing what to write: Conceptual processes in text production. Studies in writing* (vol. 4., pp. 139–160). Amsterdam, The Nederland: Amsterdam University Press.

Gero, J. S., & Reffat, R. M. (1997). Multiple representations for situated agent–based learning. In B. Varma, B. & X. Yao (Eds.), *Proceeding of the International Conference on Computational Intelligence and Multimedia Applications (ICCIMA–97)* (pp. 81–85). Gold Coast: Griffith University.

Gonzalez, F., Prain, V., & Waldrip B., (2003, August). *Using multi–modal representations of concepts in learning science.* Paper presented at the ESERA Conference on Research and the Quality of Science Education. Noordwijkerhout, The Netherlands.

Günel, M., Atila M. E., & Büyükkasap E. (2009). Farklı betimleme modlarının öğrenme amaçlı yazma aktivitelerinde kullanımlarının 6. sınıf yaşamımızdaki elektrik ünitesinin öğrenimine etkisi [The impact of using multi modal representations within writing to learn activities on learning electricity unit at 6th grade]. *İlköğretim Online*, *8*(1), 183-199.

Gunel, M., Hand B., & Gunduz, S. (2006). Comparing student understanding of quantum physics when embedding multimodal representations into two different writing formats: Presentations format versus summary report format. *Science Education*, 90, 1092–1112.

Gunel, M., Hand, B., & Prain, V. (2007). Writing for learning in science: A secondary analysis of six studies. *International Journal of Science and Mathematics Education*, 5, 615–637.

Hand, B., & Choi, A. (2010). Examining the impact of student use of multiple modal representations in constructing arguments in organic chemistry laboratory classes. *Research in Science Education*, *40*, 29–44.

Hand, B., Alvermann, D. E., Gee, J., Guzzetti, B. J., Norris, S. P., Phillips, L. M., … Yore, L. D. (2003). Message from the "Island Group": What is literacy in science literacy? *Journal of Research in Science Teaching*, *40*(7), 607–615.

Hand, B., Hohenshell L., & Prain, V. (2004). Exploring students' responses to conceptual questions when engaged with planned writing experiences: A study with year 10 science students. *Journal of Research in Science Teaching, 41*(2), 186–210.

Hand, B., Prain, V., Lawrence, C., & Yore, D. L. (1999). A writing in science framework designed to enhance science literacy. *International Journal of Science Education, 21*(10),1021–1035.

Johnstone, A. H. (1982). Macro-and micro-chemistry. *School Science Review, 64,* 377–379.

Johnstone, A. H. (1993). The development of chemistry teaching: A changing response to changing demand. *Journal of Chemical Education, 70*(9), 701–705.

Klein, U., Lenoir, T., & Gumbrecht, H. U. (2003). *Experiments, models, paper tools: Cultures of organic chemistry in the nineteenth century*. Stanford University Press.

Koç, S., Kıngır, S., & Günel, M. (2012, June). *Çoklu modsal betimlemeler eğitiminin kimya konularını öğrenmeye etkisinin araştırılması* [Investigating the effect of multi modal representation training on learning chemistry]. Paper presented at the X. Ulusal Fen Bilimleri ve Matematik Eğitimi Kongresi, Nigde Universitesi, Nigde, Turkey.

Lemke, J. (1998). Multiplying meaning: Visual and verbal semiotics in scientific text. In J. R. Martin & R. Veel (Eds.), *Reading science* (pp. 87–113). London, UK: Routledge.

Mason, L., & Boscolo, P. (2000). Writing and conceptual change. What changes? *Instructional Science*, *28*, 199–226.

Mayer, R. E. (2003). The promise of multimedia learning: Using the same instructional design methods across different media. *Learning and Instruction*, *13*, 125–139.

McDermott, M. A. (2009*). The impact of embedding multiple modes of representation on student construction of chemistry knowledge* (Doctoral dissertation). Retrieved from: http://ir.uiowa.edu/etd/253/

McDermott, M. A., & Hand, B. (2013). The impact of embedding multiple modes of representation within writing tasks on high school students' chemistry understanding. *Instructional Science, 41*, 217–246.

Milli Eğitim Bakanlığı (2004). İlköğretim *fen ve teknoloji programı (4-5. sınıf)* [*Elementary* science and technology curriculum (4–5th grade)]. Ankara, Turkey: Milli Eğitim Bakanlığı Yayınları.

Murcia, K. (2010). Multi–modal representations in primary science: What's offered by interactive whiteboard technology. *Teaching Science*, *56*(1), 23–29.

National Research Council. (1996). *National science education standards.* Washington, DC: National Research Council.

Norris, S. P., & Phillips, L. M. (2003). How literacy in its fundamental sense is central to scientific literacy. *Science Education, 87*(2), 224–240.

Pineda, L., & Garza, G. (2000). A model for multimodal reference resolution. *Computational Linguistics, 26*(2), 136–192.

Prain, V., & Waldrip, B. (2006). An exploratory study of teachers' and students' use of multi–modal representations of concepts in primary science. *International Journal of Science Education*, 28(*15*), 1843–1866.

Schnotz, W. (2002). Towards an integrated view of learning from text and visual displays. *Educational Psychology Review, 14*(1), 101–120.

Schnotz, W., & Lowe, R. (2003). External and internal representations in multimedia learning. *Learning and Instruction*, 13, 117–123.

Schonotz, W., & Bannert, M. (2003). Construction and interference in learning from multiple representation. *Learning and Instruction 13*, 141–156.

Tang, K., Delgado, C., & Moje, E. B. (2014). An integrative framework for the analysis of multiple and multimodal representations for meaning-making in science education. *Science Education*, *98*(2), 305–326.

Tsui, C.-Y. (2003). *Teaching and learning genetics with multiple representations* (Doctoral dissertation). Retrieved from http://espace.library.curtin.edu.au/R?func=dbin-jump-full&local_base=gen01era02&object_id=14027

Tytler, R., Prain V., & Peterson S. (2007). Representational Issues in Students Learning About Evaporation. *Research in Science Education*, 37, 313–331.

Waldrip, B., Prain, V., & Carolan, J. (2006). Learning junior secondary science through multi–modal representation. *Electronic Journal of Science Education, 11*(1), 66–105.

Wu, H.-K., & Puntambekar, S. (2012). Pedagogical affordances of multiple external representations in scientific processes. *Journal of Science Education and Technology, 21*(6), 754–767.

Wu, H.-K., Lin, Y.-F., & Hsu, Y.-S. (2013). Effects of representation sequences and spatial ability on students' scientific understandings about the mechanism of breathing. *Instructional Science, 41*, 555–573.

Yesildag F. & Gunel M., (2009, August). *College students' understanding and use of multimodal representations*. Paper presented at the European Science Education Research Association, Istanbul, Turkey.

Yesildag Hasancebi, F., & Gunel, M. (2013). College students' perceptions toward the multi modal representations and instruction of representations in learning modern physics. *Eurasian Journal of Educational Research, 53*, 197–214.

Yeşildağ, F., Günel, M., & Büyükkasap, E. (2008, August). *Modern fizik öğrenmede öğrenciler hangi modsal betimlemeleri önemli görüyor ve kullanıyor?* [Which modal representation are considered important and used in learning modern Physics by students?]. Paper presented at the VIII. Ulusal Fen Bilimleri ve Matematik Eğitimi Kongresi, Abant İzzet Baysal University, Bolu, Turkey.

Yore, D., Bisanz L. G., & Hand, M. B. (2003). Examining the literacy component of science literacy: 25 years of language arts and science research. *International Journal of Education*, *25*(6), 689–725.

## Annex 1.

Checklist for Communicating Science Information

TYPES OF MODES USED (Provide a number for each mode):

| | |
|---|---|
| _____ Text (Required) | _____ Pictures |
| _____ Graph | _____ Table |
| _____ List | _____ Diagram |
| _____ Math | _____ Animation |

INTEGRATING TEXT WITH MODES OF REPRESENTATION:

_____ Picture Captions

_____ Text referring to pictures (e.g. See figure 1)

_____ Alternative modes (other than text) spread throughout

_____ The use of bold, italic, or underlined words to point out important text & modes

_____ Defining key terms displayed in the modes within the text

AUDIENCE CONSIDERATIONS

_____ Vocabulary appropriate for the audience

_____ Pace & "Density" of product appropriate for the audience

_____ Alternative modes appropriate for the audience

COMMENTS:

Teacher-Created Embeddedness Rubric

| **TEXT**: | | | | |
|---|---|---|---|---|
| Grammatically Correct | **All(4)**<br>0 errors<br>_____ | **Most (3)**<br>1-3 errors<br>_____ | **Some(2)**<br>4-6 errors<br>_____ | **None(1)**<br>More than 6<br>_____ |
| Accurate | Entire Paper<br>_____ | More than ½<br>_____ | Less than ½<br>_____ | None<br>_____ |
| Covers Required Topics | All topics<br>______ | Topics<br>_____ | Topics<br>_____ | None<br>_____ |
| Thorough | All topics<br>_____ | Topics<br>_____ | Topics<br>_____ | None<br>_____ |
| OVERALL TEXT SCORE ——— | | | | |

**MODAL REPRESENTATIONS:**

Number of DIFFERENT Modes Used (other than text) ______(a)

____ Picture ____ Graph ____ Table ____ List ____ Diagram ____ Math

Number of TOTAL Modal Representations ______(b)

Number of INAPPROPRIATE Representations ______(c)

Number of TOPICS Related to Modal Representations ______(d)

OVERALL SCORE = (b – c) + a + d = ______

**INDIVIDUAL MODAL REPRESENTATIONS:**

**KEY: (N) = Next to Text (R) = Referred to in text (A) = Accurate**
**(C) = Complete (CA) = Caption (O) = Original**

**1) TYPE_______________**
**N____ R____ A____ C____ CA____ O____ TOTAL ______**

**2) TYPE_______________**
**N____ R____ A____ C____ CA____ O____ TOTAL ______**

**3) TYPE_______________**
**N____ R____ A____ C____ CA____ O____ TOTAL ______**

**4) TYPE_______________**
**N____ R____ A____ C____ CA____ O____ TOTAL ______**

**5) TYPE_______________**
**N____ R____ A____ C____ CA____ O____ TOTAL ______**

**6) TYPE**
**N____ R____ A____ C____ CA____ O____ TOTAL ______**

**OVERALL SCORE_______ # of MODES______ AVG. EB SCORE ______**

**GRAND TOTAL (RAW)______GRAND TOTAL (AVG) _______**