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HOMO SEMIOTICUS IN SCIENCE CLASSROOM: HOW FUTURE'S SCIENCE TEACHERS FACILITATE MEANING-MAKING OF SCIENCE CONCEPTS AS CITIZENS OF DIGITAL AGE?

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Abstract:
Communication of scientific knowledge is ultimately multimodal. In science education, many researchers demonstrated that design of science texts has a great role in meaning-making of communicated scientific knowledge. In order to present message, representations are essential elements that need to be designed consciously by science educators. This study investigates meaning-making practices of pre-service science teachers during learning activities. In a social semiotic approach, multimodality principles were executed to reveal how participants think about meaning-making practices, how they design their learn materials, and how they orchestrate during teaching. 41 preservice science teachers participated to study. 33 of them responded multimodal literacy scale, all of them prepared a PowerPoint™ presentation as ten groups to teach a certain general chemistry topic and classroom observations were done. It was seen that, in theory almost all pre-service science teachers have representational competence but the results stemming from real practices showed inverse. Results of this study demonstrated that there is a big gap between pedagogical concerns and meaning-making facilities in the practices of pre-service science teachers during a science instruction. It was implied that, designing learning materials that contain high meaning-making potentials and mastering to communicate it requires a theoretical and pedagogical knowledge.

Keywords: meaning-making, multimodality, science education, social semiotics

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1. Introduction

The medium is the message (McLuhan, 1967). The mediums were called as semiotic sources (linguistic, visual, audio, gestural, and spatial tools). They were produced by Homo Semioticus in order to construct the message which carries meaning. Homo Semioticus is a human being who makes meaning, investigates the process of meaning making, and questions the creation of new meanings with integrated semiotic sources (Rifat, 2018, p.7). Homo Semioticus benefits from semiotic sources in order to critique, comprehend, analyze, synthesize, and present any written and scientific discourse, text, photograph, animation, simulation, video, sound and etc. (modes) with the help of metalanguage (Rifat, 2018, p.8). Homo Semioticus looks at the world as a meaningful and finite text. The one also realizes that it is an infinite integrated text which includes various semiotic sources within different multiple modes. Although, the world, which surrounds Homo Semioticus, includes several understandable and cognizable relations which construct meaning, these relations do not always include accurate, prominent, and indisputable properties. Moreover, meaning may not be transferred only through written texts but also it is transmitted by means of speech, gesture, and reaction (Oliviera, Rivera, Glass, Mastroianni, Wizner, and Amodeo, 2014; Rifat, 2018, p.15). That is, meaning is inherently conveyed with different type of modes called as multimodal text. Thus, Homo Semioticus may construct and comprehend multimodal text efficiently while transferring message. Multimodal texts are defined as texts that comprise of two or more semiotic systems, or modes (i.e., linguistic, visual, audio, gestural, or spatial) (Shanahan, 2013). Jewitt and Kress (2003) defined *modes* as an "*organized set of resources for meaning-making*" (p. 1), where different signs function together in interactive and interrelated ways (Kress, 1998). Bezemer and Kress (2008) also described modes as "*socially and culturally shaped resources for making meaning*" (p. 171). These resources include image, writing, layout, speech, and moving images, all of which can be utilized as learning resources. Bezemer and Kress (2008) highlighted "*meanings are made with a variety of modes and always with more than one mode*" (p. 171).

In this context, The New London Group (1996) claimed that Homo Semioticus may have different type of literacy skills. This may defined as multimodal literacy skills which include (1) acquring, (2) comprehending and analyzing, (3) evaluating, (4) constructing, then presenting these re-created multimodal texts. The New London Group defined being "*multiliterate*" is to be "*socially and cognitively literate with all modes of communication*" (Anstey and Bull, 2006, p. 23). Kress (2010) also stated that multimodal literate person may determine which signs or modes interrelate first. Accordingly, Homo Semioticus may perform meaning-making in a dynamic process involves providing appropriate sources for meaning and creating opportunities for re-construction of meaning.

In the modern world, the message context and tools re-conceptualized over the last 30 years with the help of rapid transformation of information technologies. They changed in response to social, economic, and especially technological issues (Daniellson and Selander, 2016). The society started to experience dynamic growth in technology

and rapid emergence of new forms of communication tools for transferring and making meaning. Technological developments have yielded communication tools that have evolved and shifted the ways in which a person interacts with another person and with the nature. The communicational transformation of messages from pages to screen had showed itself, and we have been witnessing this transformation as being directed to virtual reality. The development of communication and representation tools as well as digital environments like Web 2.0 tools enables us to combine reading and writing materials with diverse and often quite complex elements of images, music, sound, graphics, photography and film (Walsh, 2010. p. 211). By means of unique and unified message tools, Homo Semioticus may interpret, represent, and construct meaning in transaction with multimodal texts within and across several modes: visual, spatial, gestural, and kinesthetic (Sarafini, 2010; Kress and Van Leeuwen, 2001; Jewitt, 2012). That is, in the modern world new generations encounters social, textual, digital, and technological multimodal texts like Microsoft Software, Facebook, Twitter, Instagram, Snapchat, Youtube, and the other Web 2.0 tools that presents meaning; and also these tools provide them opportunities of re-creating and presenting meaning (Edwards-Groves, 2011, p. 49). Hence, the new generation should be a Homo Semioticus who easily transfers and constructs meaning with new communication tools by interrelating and integrating various types of semiotic sources.

In this context, science teachers in schools should be also a Homo Semioticus to keep up with evolving next generations' language which has best potential to make meaning and to teach the subject matter. Since, multimodal texts are ubiquitous in any discipline as well as in learning and teaching resources in all levels. For example, during a science class, students might be listening to a professor who lectures about density concept. The professor uses PhET simulation program which includes graphics, symbols, moving pictures, variables, and formulas. When the professor is manipulating variables, graphics, moving pictures is also changing. During this process, the lecturer and students are consuming different number of semiotic sources, so both of them should gain ability to use, acquire, comprehend, analyze, and synthesize these multiple modes properly (diSessa, 2004). The other example is that ionic bond in chemistry is usually taught in various ways (like words, chemical symbols, images, simulations, video, and etc.), thus teachers provide meaningful pathways with semiotic sources to students who should aware of practicing why the different semiotic sources are used and combined in a specific ways (Danielsson, 2013; Kress, 2004; Lemke, 1998; Tang and Moje, 2010; Tang, Delgado, and Moje, 2014, Unsworth; 2001). Moreover, scientists and scholars should be Homo Semioticus because various proposed theories, hypothesizes, and research articles are represented by graphs, figures, diagrams, and etc. For instance, major concepts like thermodynamic include lots of hypothesis, concepts, laws, and theories that do not only represent with only one mode (Lemke, 2000). Hence, Hawisher and Selfe (2004) and Lemke (1998) pointed out that if teachers and students do not multimodal literate as a Homo Semioticus, while designing any type of multimodal text, they may encounter difficulties associated with the language of science along with its mode of representation. Apart from these reasons, many literacy scholars proposed

that reading and writing in new digital world requires new skills (Baker, Pearson, and Rosendal, 2010; Kress, 2003; Leu, Castek, Coiro, Gort, Henry, and Lima, 2004; Klein and Shinas, 2012). O'Hollorran, Tan, and Marrissa (2015) also advocated that print-oriented and monomodal based traditional forms of language is inadequate to meet the needs of the new multicultural new world.

1.1 Classroom Context and Representations in a Semiotic Approach

The main challenge today is to move past the focus on content and oriented science education towards building meaningful and sustainable relationship among knowledge, humans, and the life world, thus introducing ethical (Dierkes and Von Grote, 2005) epistemic (Erduran and Dagher, 2014; Nola and Irzik, 2006) and aesthetic (Galison and Jones, 2014; Gilbert and Eilam, 2014) issues traditionally absent from previous, content-oriented approaches. In particular, fostering a more active student participation appears as a central concern, with much recent research oriented towards the design of "*effective texts for students to view, manipulate, and interpret*" (Prain, 2009). In particular, an approach that introduces different modes contributes to increased motivation and engagement, especially in subjects such as physics; "*by providing alternate mental pathways to access these subjects*" (van der Veen, 2012).

Success of an instructional activity depends on how the concept of learning is handled (Patron, Wikman, Edfors, Johansson, and Linder, 2017). In other words, teaching and learning potentials during a lesson emerges when the meaning-making of a disciplinary related aspects enhanced. In a social semiotic perspective, teachers need to have reasoning about their use of representations considering the situation in which all meaning-making facilities are constructed in the communication of those disciplinary relevant aspects. Patron et al. (2017) reports that; If the meaning-making is aimed to happen in "appropriate", "holistic", and "meaningful way", teachers need to account three fundamental components as followings:

- "The disciplinary relevant aspects"
- "Insight into critical features that will potentially present challenges to the discernment of any of the disciplinary relevant aspects (or their parts)"
- "A semiotic approach that is built on dimensions of affordance and variation in ways those provide optimal possibilities for access to the needed discernment."

Those statements imply that obtaining disciplinary relevant aspects does not suffice requirements of meaningful communication and so meaning making of the content. Teachers need to discern challenges which can make the communication of those disciplinary relevant aspects more difficult in science classroom. Therefore, pre-service teachers as future teachers should cope with these challenges. The idea of Patron et al. (2017) finally embraces a view that a semiotic approach will propose and facilitate affordances for meaning making systems in science classroom. Teachers need (1) a semiotic awareness (Kress and van Leeuven, 2006), (2) representational competency for design, and (3) use of meaning making affordances. Furthermore, meaning making of science content is beyond "*written and spoken words*" and it can be taught as "*a dynamic communicative process wherein utterances, actions, and pictorial representations are socially*

shared and allow for joint construction of meaning by teachers and students" (Oliviera, et al., 2017). Put differently, meaning making in science classroom involves visual, gestural and spatial components of communication (Jewitt, Kress, Ogborn, and Tsatsarelis, 2001).

2. Literature Review

Introducing multimodal artifacts fosters meaningful interactions and collaboration (Brown and Crippen, 2017; Waldrip and Prain, 2017; Tang, Delgado, and Moje, 2014; Siry and Max, 2013; Chang, 2017; Manghi and Cordova, 2011; Basu, Barton, and Tan, 2011). In this regard, representations are considered as the semiotic affordances each of which conveys a specific meaning in educational communication (Patron and et al., 2017; Brandstetter, Sandmann, and Florian, 2017). A science teacher as a Homo Semioticus wishes to comprehend and use representations as semiotic affordances to facilitate meaning making of the content. Teaching of chemistry is one of the research fields in which visual representations have been used and studied (Patron et al., 2017). However, various theoretical approaches employed for design and use of visual representations. For example, some researchers (Carney and Levin, 2001; Daly and Unsworth, 2011; Herlingher, Höffler, Opfermann, and Leutner, 2017; Meneses, Escobar, and Veliz, 2018) focused design of visuals in the perspective of image-text relations considering the cognitive processes. Some researchers focus on the meanings given learning materials in a particular social context (Halliday, 1978; Kress and Van Leeuven, 2006) and the use of those meanings in a multimodal approach of communication of scientific knowledge. (Multi media- principle) (Carney and Levin, 2002).

Meaning making process involves following components in science classroom. Those are (1) supplying available designs, (2) engaging students into designing of their personal meanings, and (3) facilitating a classroom environment where students will have opportunities to communicate their designs (The New London Group, 1996). Teachers may be conscious of substantial roles of out of school learning habits of students in this three-step process when they design their teaching strategies. In this respect, as Patron et al. (2017) asserted previously, providing appropriate meaning making facilities involves (1) disciplinary relevant aspects, (2) discerning of challenges for meaning making and (3) using a semiotic approach to create affordances against challenges. Therefore, teachers should start with /providing appropriate available design elements which are representations such as drawings, models, diagrams, animations etc. in the context of teaching of science and its disciplinary relevant aspects. However, using representations like pictures or drawings merely do not ensure success of meaning-making (Herrlingher and et al., 2017). However, unintentionally or unconsciously designed visual text may negatively affect learning (Oliviera et al., 2014). A social semiotic reasoning approach (Fredlund, Airey, and Linder, 2015) may guide teachers to comprehend challenges in communication of meaning and to determine and facilitate meaning making affordances. Besides Prain and Tytler (2012) highlight the substantial role of teacher in scaffolding students' activities involving representations.

The act of providing resources for meaning-making of scientific knowledge could create sociocultural and contextualized settings for practicing particular knowledge domains (The New London Group, 1996).

Executing action of providing appropriate available design includes three main steps. Firstly, designer determines appropriate sources for learning. Secondly, designer discern pedagogical challenges of those sources. Thirdly, incorporating bodily semiotic modalities (gestures, voice tone, and spatial relations) communicate their science knowledge with their students to orchestrate the teaching-learning activities. Homo Semioticus is expected to comprehend those three criteria. Accordingly, providing meaningful available designs in the science classrooms is thought as the first step of inquiry to engage student in a process in which they design products of their own understanding. In this respect, this study firstly aims to investigate the representational competency levels of sophomore pre-service science teachers to reveal how they design teaching and learning materials regarding meaning-making enhancements. Secondly, current study aims to investigate bodily semiotic modalities during a learning activity. In a different aspect, but implying similar things, teachers, and students should recognize, use, obtain, comprehend, analyze, synthesize, and present multimodal text as a Homo Semioticus in order to attend active learning environment which includes many semiotic sources (Baker, Pearson, and Rozendal, 2010; Kress, 2003; Kress, 2010).

2.1 Theoretical Framework

2.1.1 Semiotics

Theoretical foundations of semiotics go back to studies of American scientist Charles S. Peirce and Swiss scientist Ferdinand de Saussure. The purpose of semiotic is to analyze any meaningful sign in the universe of discourse. These signs could be languages, behaviors, gestures, audios, photos, multimodal texts and etc. which construct and represent meaning. Semiotic or semiology aims to trace the process of making meaning in any types of text (Guiraund, 1994: s.20). In other words, semiotic literacy aims to present meaning in any sign with the help of a metalanguage after analyzing them (Rifat, 2009: s.58).

The sign which is the main concern of semiotic represents some other meanings outside of itself, it is in general qualitative of something else (Guiraund, s.18-19). A figure in a table, in a literary form a hero's purpose or behavior can be regarded as a sign can be regarded as sign (Caglayan, 2017). In a broad term, the sign has features that allow it to take the place of something else -an object, a phenomenon, an entity that can be identified, an image that is perceptible, an image of meaning- which is a stimulus that can be recalled when it is connected to the image of another stimulus (Caglayan, 2017).

In conclusion, semiotic does not only examine linguistic signs, but also investigates every sign which represents a meaningful whole in four distinct disciplinary forms. It focuses on examining (1) meaningful signs, (2) meaning of signs, (3) usage of signs in any text, (4) impacts of them (Rifat, 92: s.6).

2.1.2 Social Semiotic Theory

The social semiotic theory put forth that meaning and complexity of signs in any text depended on readers' and writers' skills and interests as well as culturally and socially embeddedness (Jewitt, 2005; Kress, 2010; Kress and van Leeuwen, 1996). That is, the creator of signs represent them in a designed specific multimodal text and the design was naturally impacted by properties of economic, social, cultural, political, and economic patterns of society (Jewitt, 2003). In this sense, Homo Semioticus may interpret both signs and the design that reader and creator brings to the text (van Leeuwen, 1998). Hence, the social semiotic theory enables a crucial framework for this study, because Homo Semioticus obtain, analyze, synthesize, construct, and present a multimodal text in the intersemiotic relationships that reflect their social and cultural environment.

The early theoretical foundation concerning multimodality was stemmed from Halliday's (1978) social semiotic approach to language. Although Halliday's initial concern was to improve a linguistic framework (i.e., SFL), various theorists in the 1990s started to extend his theory to contain other semiotic systems of meaning such as images (Kress and van Leeuwen, 1996), music (van Leeuwen, 1998), movement and gesture (Martinec, 2000), and mathematical symbolism (O'Halloran, 2000).

2.1.3 Multimodality and Multimodal Literacy

There are three main assumptions that address the concept of multimodality. The first states that language is the most important mode of communication, speech, or writing in semiotic but this is not the main component in modern world's society (Jewitt, 2013, p.2; Norris, 2004, p.3). Thus, representations and communication tools should be designed according to selection and utilization proper modes for given purposes (Jewitt, 2013). Second assumption expresses that multimodal text has been constructed in their social, cultural, and historical environment (Jewitt, 2013, p.3). Moreover, Goswami (2011) indicated that multimodality text is impacted by neurocognitive mechanisms of individual. That is, prior experiences and psychological aspects influence multimodal texts.

Third assumption asserted that meaning in multimodal text is constructed through orchestrating creators' selection and configuration of different modes (Jewitt, 2013). In other words, meaning making is the process of interactions and interrelations that take place within and between different modes. Accordingly, Olivierat et al., (2017) proposed that modalities create meaning are inherent in verbal, pictorial, and gestural modes of communication. Therefore, Homo Semioticus may intersect new communicative avenues in digital age, so they should be aware of the affordances of modes, modal configurations, and the semiotic potential involved in a contemporary universe of discourse (Jewitt, 2013).

Kress and van Leeuwen (2001) defined multimodality as "*the use of several semiotic modes in the design of a semiotic product or event, together with the particular way in which these modes are combined*" (p. 20). The term "multimodal" is a semiotic tool which enriches written linguistic modes of meaning with specific elements of visual, audio,

and spatial patterns of meaning (Cope and Kalantzis, 2000). These patterns of meaning was called as a *metalanguage* by The New London Group (1996), it includes three properties of meaning that can be easily captured in any multimodal text (Halliday, 1978). (1) Ideational meaning is about making thematic content about the world, (2) interpersonal meaning is determining stance and relationship toward oneself and other people, (3) textual meaning is interrelating different elements into a meaningful text.

These three kinds of meaning can be applied for any type of multimodal text while constructing and representing them. Moreover, the metalanguage was offered by The New London Group (1996) may apply in every context while analyzing, such as English (Benson, 2008), Mathematics (O'Halloran, 2000), Visual Arts (Duncum, 2004), Music (Pramling and Wallerstedt, 2009), or Science (Kress, Jewitt, Ogborn, and Tsatsarelis, 2001).

In this context, multimodal literate person -Homo Semioticus- can be defined as "*socially and cognitively literate with all modes of communication*" (Anstey and Bull, 2006, p. 23). Homo Semioticus has abilities to construct meaning in increasingly multimodal ways with the help of contemporary communication tools- a component of the theory of multi-literacies (Cope and Kalantzis, 2000). They have capabilities of interrelate and integrate linguistic, visual, audio, gestural, and spatial designs around a meaningful multimodal design (The New London Group, 1996).

2.1.4 Representational Competency

Using semiotic resources embedded to cultural context (Kress and van Leeuven, 1996) promotes science learning while creating meaningful representations (Tippet, 2018). Regarding the interest of this study, cultural context of meaning involves disciplinary relevant aspects or "*the agreed meaning-making functions that a semiotic resource fulfills for a particular disciplinary community*" (Patron et al., 2017). Designing visual representations using different modes seems a strong requirement of effective teaching in classrooms (Airey and Linder, 2009) because different modes may demonstrate different aspects of disciplinary phenomenon and may help individuals to make a comprehensive meaning of the content. Representational competency (diSessa, 2004; Kozma and Russell, 2005; Stieff, 2011; Gebre and Polman, 2016) entails comprehending "*multiple modes of representation, the creation of new representations, the conventions and traditions presented in multiple modes, the transformation between representations, and the form and function of specific aspects of representations*" (Tippett, 2018). In this respect, representational competency encompasses three elements of what of pedagogy of multiliteracies: available designs, designing, re-designed (The New London Group, 1996). What of pedagogy focuses on the term of design as a metalanguage of multiliteracy. Design term implies that learning and meaning making is a result of combination and construction of multimodal text. The term also describes a process as a semiotic activity in which students or teachers produce or consume multimodal text through three steps: available designs, designing, re-designed. Available designs posit comprehending the grammar of given semiotic resources such as grammar of language, visual, and video. Designing refers to re-representation and re-contextualization of available designs.

During designing, learner works with principles of available designs to transform old ones into new use of old texts. Re-designed implies communication of the individual designs, it is a transformed meaning, and it is a new meaning making resources (a novel available design element). Representational competency, accordingly, considers all meaning making systems in order to handle conceptions of learning. Representational competency engages creating visual representations by using available design of learning materials and to promote learner understandings of visual representation (Schnotz, Ludewig, Ullrich, Horz, McElvany, and Baumert, 2014). Put differently, science teacher as a Homo Semioticus is a human being who struggles to use all modalities of communication to promote meaning-making in teaching of science.

Meaning is derived not only from words but also pictorial representation and gesture (Jewitt 2008; Lemke, 1998). Oliviera et al. (2017) stated that gesture of a science teacher has two main functions; firstly "pointing to objects in the immediate physical setting" and secondly "*representation of intangible process and ideas*". They add that those gestural acts have a substantial role in sense making. Moreover, communication and interactions in science classroom involve verbal and non-verbal signs. Verbal signs are words, intonation patterns, and graphic signs. Non-verbal signs include "*gestures, bodily postures, facial expressions, tones of voice, visual forms*" (Sebeok and Danesi, 2012, p20). Sebeok and Danesi (2012) express that "*gesticulants*" convey demonstrations those are invisible in speech and they are surrogating to form meaning. According to van Leeuven (2005, p2) semiotics does not focus only on speech, it also addresses the elements which structure all forms of meaning and signs that are patterns of meaning by taking the forms of "*words, images, sounds, gestures and objects"*. This consideration implies that verbal and nonverbal semiotic sources are needed to be synchronized while delivering a speech that intends to communicate with all forms of meaning. This idea is in line with the concept of Homo Semioticus (Rifat, 2018) who wishes to construct meaning by using all elements of it from the use of hands to tone of the voice.

This study explores the answer of the question that whether participants of this study can be considered as Homo Semioticus or not? In the lights of all considerations, arguments and previous empirical findings in relevant literature, the idea of multimodal literacy and representational competency were used as an ideational and functional tool to investigate the situation whether participants can be thought as Homo Semioticus. Idea of representational competency proposes an action to promote and enhance meaning making in learning activities. Therefore, it focuses on the situations in practice. Representational competency was considered firstly as creating and designing effective mediums through which the concept of learning is presented and secondly benefiting bodily semiotic modalities in science classroom.

2.2 Purpose of the Study and the Research Questions

This study has two aims. First, it aims to investigate pre-service science teachers (PSTs) views about their own representational activities and secondly it aims to investigate how PSTs practice those meaning making affordances in real instructional circumstances. In other words, deciding whether participants PSTs are Homo-

Semioticus, their representational competencies in theory and in practice were investigated. In this respect, to address those goals, research questions were determined as below;

1. How junior PSTs conceive their meaning making practices and affordances during an instruction?
2. How are representational competencies of junior PSTs in teaching of certain science content?

3. Method

The researchers used sequential explanatory mixed method research design in this study. In the first step quantitative data was collected through a multimodal literacy survey. In the second step generated teaching artefacts and field notes from classroom observation was collected as a qualitative data in order to explain survey results efficiently.

3.1 Sampling

41 junior pre-service science teachers -who were selected through convenient sampling- participated into the study. In the first phase 33 in 41 participants answered multimodal literacy survey. In the second step, nine heterogeneous groups consisted of from 33 students were observed by one of the researcher and one expert who filled an observation checklist, the non-participant observer also took notes during their presentations to obtain qualitative data. Groups elected one presenter-teacher for each of their presentations. Participants joined the study according to volunteerism. Required official permissions were taken from administration of the Faculty of Education.

3.2 Data Collection and Instruments

3.2.1 Multimodal Literacy Scale

Addressing first research question of current study, multimodal literacy test that was previously prepared by (Bulut, Ulu, and Kan, 2015) was applied. The test had Likert-type responses (5 = strongly agree…1 = strongly disagree). The test was prepared as reflecting three themes. Those themes are expression, sense making, and preferring. The reliability coefficient of each theme is higher than .70. The overall Cronbach-Alpha internal consistency coefficient is identified as .87. The first theme is expression category in which first five items explores whether participants use multimodal resources in the expression of the content of instruction or not. The second theme is sense-making theme in which -from sixth to eleventh- items attempt to reveal whether participants use multimodal and semiotic sources to promote meaning making in instructional contexts or not.

The last six items are inferring theme which attempts to reveal how participants perform their teaching source or material (Appendix -1).

3.2.2 Classroom Observations and PowerPoint™ Presentations

Concerning the second research question, the study focused on communication of scientific knowledge in science classroom. Communication in science classroom draws on semiotic sources inherent in various modalities. van Leeuwen (2005, p.3) described semiotic sources as "*the actions and artefacts we use to communicate*". In this research the semiotics sources used by pre-service science teachers through an instruction of a particular chemistry concept are investigated. In this regard, this study is interested in semiotic sources in action those are laid in the speech and narration, and semiotic sources in artefacts as the presentations generated by the participants. To investigate the semiotic sources in action (Van Leeuven, 2005) classroom observations were planned by one of the researchers.

As it was discussed before, this study investigates the idea of representational competency in the light of Gebre and Polman's (2016) framework. We had two types of sources of data in order to assess whether the participants are representational competent or not. The first one is participants' learning material (the presentations they created) and second one is bodily semiotic modalities during teaching performance. Gebre and Polman (2016) developed three criteria to assess representational competency: representational variations, dimensionality of representations, and representational adequacy. First two of them are for analyzing and assessing participant generated artefacts (PowerPoint™ presentations), the last one is engaged to analyzing and evaluating the semiotic sources in action in a social context of learning. The last one involves bodily semiotic modalities that consist of gesture, vocal tone, and spatial relations during the act of teaching.

Following a brief informing of our aims and procedures, participant-generated PowerPoint™ presentations were collected with PSTs' permissions. At the beginning of the study and after getting official permissions, participants were informed about the procedures of the study and about classroom observation. Participants were informed about that there will be no video or voice recording but the observer will take field notes. Participants were not informed about the criteria for taking field notes due to concerns about preserving naturality during lessons.

Observation is a data collection method which is applied in a particular social context to have a direct connection (Polkinghorne, 2005). In real context, researcher observes, listens, and takes notes of the actions of participants in a perspective that reflects theoretical framework (multimodality and social semiotics) of the study. Observation is generally associated with ethnographic study (Cresswell, 2007), but this study does not involve deep cultural analysis. It involves the actions of a person in a specific social context during a social communication and interaction processes. This action includes participant behaviors highlighting semiotic sources in communication of knowledge and the means through which they try to enhance meaning-making in the communication of disciplinary relevant aspects.

Observed bodily semiotic modalities during content presentations were the use of body language, voice tone, and the spatial relationship with audience (on which place in the classroom the instructor stances or getting closer to participants at

particular instants). Those semiotic sources in participants' actions during presentations were considered as significant factors because representational competency does not just engage designing texts and presenting to the audience (Jewitt, 2008).

Cole (1996) put forth that human mind is constructed through social interactions as a principle of sociocultural theory. Furthermore, Townsend, Brock, and Morrison (2018) reported that "*effective facilitation of the use of semiotic systems in our sociocultural contexts can promote shared understandings and shape the ways people construct knowledge*". They were significant because they enhance the communication (Kress and Leeuwen, 2001).

Classroom practice observations were done in a nine-week long presentation series in general chemistry laboratory course's theoretical instruction sessions. For each lesson participants prepared and designed science topic (general chemistry topics) with a PowerPoint presentation. Technological and digital tools in the classroom were an interactive smart white board, a projection device, speakers, and a laptop. Instructional devices and digital sources in the classroom seemed sufficient enough to create and execute comprehensive representations. As mentioned before, during the content presentations, one of the researchers observed and took field notes. In the end, the researcher took permission of participants for taking a copy of the PowerPoint presentation to analyze and evaluate the representational competency of those learning materials.

We developed observation criteria that were generated from the multimodal literacy scale (Bulut, Ulu, & Kan, 2015). As it was mentioned above, the focus was on gestures, tones of voice, and spatial relations. In this regard, we determined items of the multimodal literacy scale related the semiotic sources abovementioned. Item 7, 8, and 12 were chosen as observation criteria to score the performance in the use of semiotic sources during teaching. Scoring of the performance was done in the same wise of the Multimodal Literacy Scale as grading the performance from 1 to 5. During observations, the observer researchers took notes and eventually did grading of the item as described in the followings;

For the first item (Item-7 in the scale), the observer took notes about, in how frequently the presenter used arms and hands movements, nods and head shakes. Sebeok and Danesi (2012, p66) expressed gesture as "*the use of hands, the arms, and to a lesser extent, the head, to make bodily forms of all*". Cobley (2005, p.47) also stated that "*Gesture is usually refers to any visible bodily action expressing thought or feeling or that plays a role in symbolic action*". For the second item (item-8 in the scale), the observer paid attention to whether the presenter had an effort to interact with the audience or not. In how frequency, the presenter changes her/his location, gets closer to the audience or some particular one who misses the point of subject. In the last item (Item-12 in the scale), the observer paid a particular attention to tone of the voice. Given attention was on the frequency of up and downs in the volume to examine whether it was monotone or not. After soon observation, observer scored to each of performances from 1 to 5 regarding his notes and impressions. A further evaluation of scores was done with the second author according to the field notes.

Table 1: Observation Criteria and Scoring

Teacher uses arms and hands movements, nods and head shakes, and mimics.	1	2	3	4	5
Teacher changes her/his location (spatial position) during lesson and interacts with students.	1	2	3	4	5
Teacher variates tone of her/his voice and create a vocal effect on her/his words.	1	2	3	4	5

4. Results

Descriptive statistics summarize and organize the information obtained for inferencing. Below quantitative results of Multimodal Literacy Scale Test are presented. Descriptive statistics facilitated means of each category. Mean of sense-making category was found as 3,65 over 5, for expression category it was found as 4, 24 and for preferring category it was found as 1,81 (it can be considered as 4,19 over 5).

Table 2: Groups' Descriptive Statistic Results

Group Statistics				
	N	**Mean**	**SD**	**St. Error**
Sensemaking	33	3,6580	,43586	,07587
Expression	33	4,2424	,60365	,10508
Prefering	33	1.8121	,73133	,12731

Second type of data involves participants generated teaching artefacts as PowerPoint™ presentations. Gebre and Polman (2016) proposed a model for analyzing presentations was recruited. They developed following procedures to analyze and evaluate in terms of semiotic and multimodal sources and affordances that aim to promote meaning making of conceptions of learning. The procedures were employed in order to investigate representational competency of participants and representational adequacy of attendant-generated artefacts or visual representations. This qualitative analysis approach includes three subsections of representational competency as representational variations, dimensionality of representations, and representational adequacy.

Representational variations involve a categorization of non-text representations as iconic/symbolic, schematic, and charts/graphs (Gebre and Polman, 2016). Iconic/symbolic representations include images posing a "*physical structure*" of the concept such as "*public bathroom doors and visualizations used in flight safety instruction manuals*". Symbolic representations are used to visualize the things which do not have physical form such as traffic signs or warnings, and they are "*more abstract*". Schematic representations consist of higher order meanings that could be relationships or hierarchies between concepts, or processes such as diagrams, graphs, or other ways to present quantitative data to decrease abstractness (Gebre and Polman, 2016). The analysis criteria determine the number (frequency) and variety in the use of those non-textual representations. In other words, non-textual representations are considered to enhance meaning-making and the more use of them and the more variety in the use are

considered as a way of improving representational competency. The variety issue is related to make an inference to decide whether participants used appropriate and intentional use of representation to construct meaning about particular aspect of "object of learning" or not. In this respect, first criterion of representational competent or to be Homo-Semioticus, included a frequency and variety analysis of non-textual representations and a mathematical depiction as given in the Table 3 below.

Table 3: Types and frequencies of groups' representations

Groups		Representations	Frequency
1	Number of representations	One	6
		Two	4
	Types of representations	Iconic/symbolic	11
2	Number of representations	One	7
		Two	1
	Types of representations	Iconic/symbolic	1
3	Number of representations	One	7
		Two	1
		Three	1
	Types of representations	Iconic/symbolic	5
4	Number of representations	One	7
		Two	1
	Types of representations	Iconic/symbolic	2
5	Number of representations	One	20
		Two	6
		Three	3
	Types of representations	Iconic/symbolic	8
		Schematic	3
		Graph/Chart	4
6	Number of representations	One	12
		Two	4
	Types of representations	Iconic/symbolic	9
		Schematic	1
7	Number of representations	One	7
		Two	3
	Types of representations	Iconic/symbolic	5
		Schematic	1
8	Number of representations	One	6
		Two	2
	Types of representations	Iconic/symbolic	3
9	Number of representations	One	12
		Two	7
	Types of representations	Iconic/symbolic	10
		Graph/Chart	5



Figure 1: Sublimation of naphthalene, (b) aspirin synthesis

Current study analyzes the nature of students' representations by coding non-text representations into three classifications: iconic/symbolic, schematic, and charts/graphs. Students use iconic representations to recall images of referent (Lemke, 1998). Schematic representations enable students to show represent relationships, hierarchies, and flow of processes between components. Charts/graphs are mainly built to organize concretize abstract data.

After coding representations types, the study showed types and fruquencies of students- generated representations. Of the 89 presentations, only 37% include non-text representations in order to foster meaning making with using multiple representations. In all presentations, 60 have two types, 29 have three types of representations (Table 3). Findings revealed that pre-service teachers dominantly used iconic/symbolic representations (79%). Only three percentages of students' artefacts include schematic, and six percentages consist of graph/chart representations in order to contextualize topic.

Pre-service teachers used iconic/symbolic representations generally as only for description of object. These icons only remind visual mode of the object, do not serve as adding a new meaning. For instance, Figure 1(a) was used for telling sublimation of naphthalene as a mental reminder, Figure 1(b) was used for teaching aspirin synthesis. Both of them could not be helpful to reader about intended subject.

Students also used schematic representations rarely to depict processes such as in change of state and soap manufacturing. Figure 2(a) represents interaction and interrelation between states by revealing progression. Figure (b) shows steps of soap experiment sequentially.

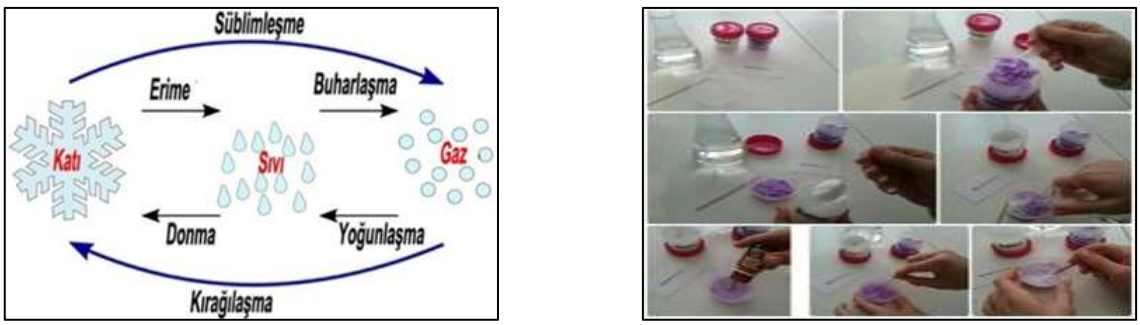


Figure 2: (a) Change of state (b) soap manufacturing experiment

Graphs and charts are another type of representations used in students' artefacts. Students generally used them for concretizing abstract quantitative data. Figure 3(a) represents a pH scale with examples. It indicates pH degrees of different matters with colors which addresses strength of acidity and alkalinity. For example, red color is stronger than orange one in terms of acidity. Figure 3(b) represents the relationship between volume-temperature and density-temperature.

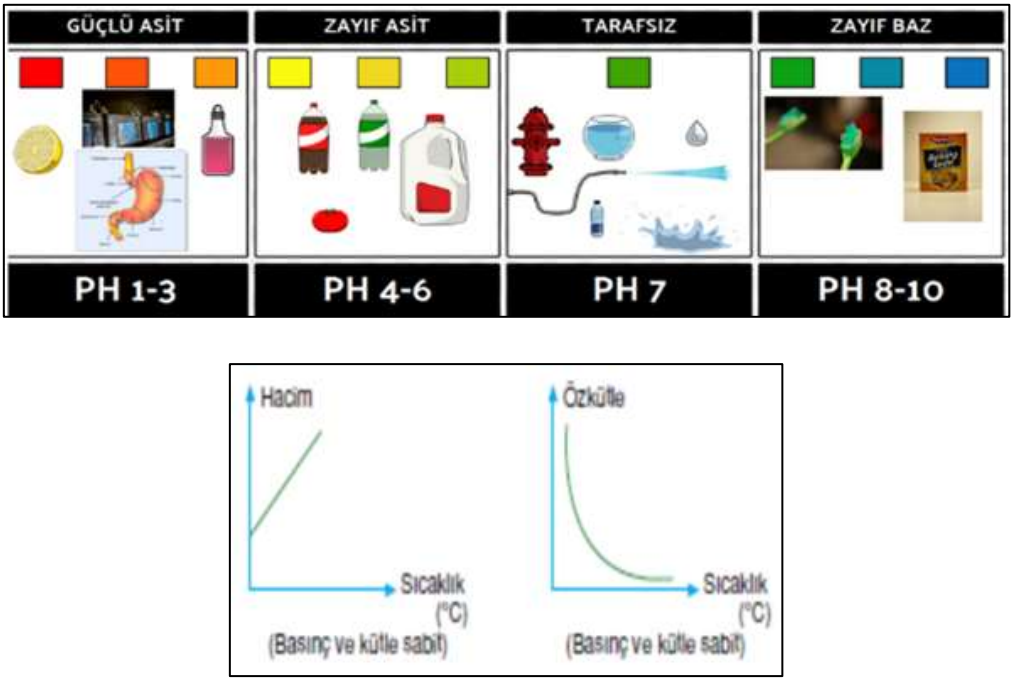


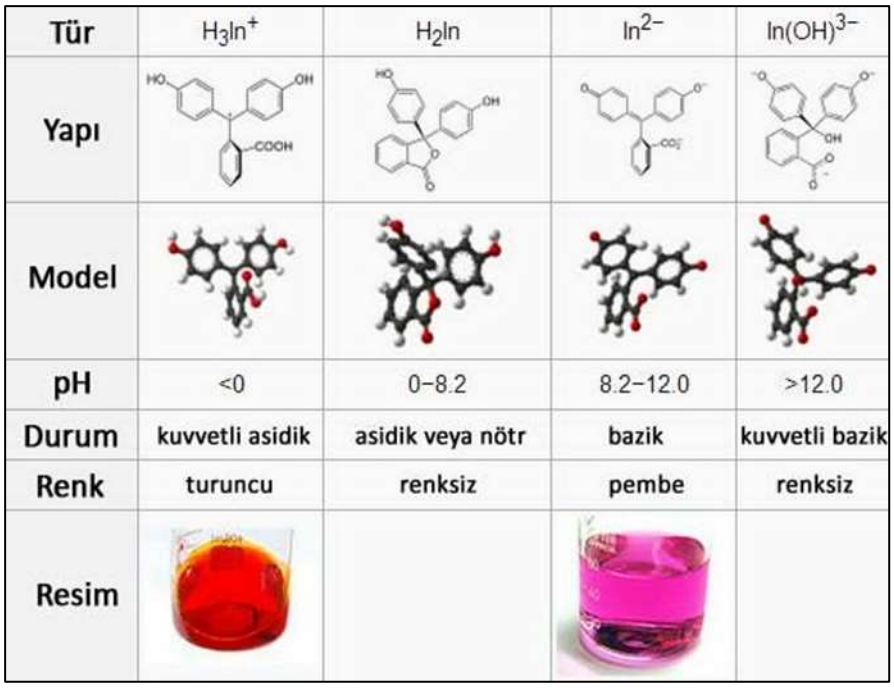
Figure 3: (a) pH scale (b) Density-temperature relationship

Second criterion of representational competency is dimensionality of representations. Gebre and Polman (2016) conceptualized dimensionality as "*a metric for semiotic richness*". Dimensionality investigates and analyses functions of each representation whether it presents a new information or it just repeat previous one for the context. In other words, it helps to analyze what each representation contributes to the overall-meaning (Gebre and Polman, 2016). Gebre and Polman (2016) determined dimensionality for each artefact by calculating a specific ratio. The ratio was measured with a mathematical method which defined as "*dividing the number of dimensions from non-text representations by the number of non-text representations*" in same artefacts. The ratio was considered as a "metric" of semiotic richness which implies communicative competencies of scientific knowledge. The ratio below 1.0 means no contribution to overall message and over 1.0 implies "*allowing multiple layers of comparison or insight for readers*" (Gebre and Polman, 2016).

Table 4: Dimensionality ratio of groups

Groups	Ratio
1	≤1
2	≤1
3	≤1
4	≤1
5	**1≥**
6	≤1
7	≤1
8	≤1
9	≤1

Representation of fifth group except from others (Figure 4), includes three dimensions about structure of phenolphthalein: molecular geometries, ball and stick 3D models, and their reactions towards different strength acids. That is, this representation involves three types of non-text presentations such as geometric shapes, 3D models, and visuals in order to improve meaning making. Dimensionality ratio of this presentation is bigger than one.



(1) Molecular geometries of Phenolphthalein which has different radical groups

(2) Ball and stick models of different Phenolphthalein

(3) Phenolphthalein reactions towards different acid degrees

Figure 4: Properties of different radical grouped phenolphthalein

4.1 Data Obtained from Field Observations

Last criterion to evaluate representational competencies of the PSTs is representational adequacy was employed. According to Gebre and Polman (2016), representational adequacy means "the extent to which the infographic is complete enough to communicate the intended message with sufficient/proper context and information for readers". In a similar concern to Gebre and Polman (2016), in this study, one of the researchers participated each teaching practice, observed participant performances and

finally evaluated bodily semiotic modalities that intend to orchestrate the communication between the generated representations and the learners.

The implementation of last criterion differs from Gebre and Polman (2016) at the point that, they deemed representational adequacy as an aspect of generated visual and the active interaction occurs between the representation mean and the learner during the meaning-making process. However, the difference of the current study is that the designer of the representation has an active role during the meaning making of the content and enhances the communication between learner and learning material. Therefore, representational adequacy here is implied as an aspect both the teachers and the learning material they have. Here, aspects of representational adequacy are considered as an active synchronization between semiotic sources that the teacher use (gestures, voice tone, and spatial relations) and semiotic sources and multimodality in their representations. In other words, when the variation in representations emerges (the first criteria), a variation in the semiotic sources in teacher performance is expected. This idea fits with the communication of the redesigned (The New London Group, 1996).

As mentioned before, one of the researchers and one expert at representational competency attended lessons as non-participant observers and took field notes, and ultimately gave scores to each criterion. To verify the results all researchers analyzed the observation field notes and made agreements on the scores. In Table-5 below, the scores are given. As it can be seen, the total score of each criterion did not exceeded half of the total score. It was seen that the use of gesture was seen most semiotic source in the discourses and semiotic sources stemming from spatial relations is the least with a relatively low score.

Table 5: Scores of Observation Criteria

	First Criterion		Second Criterion		Third Criterion	
	Rater 1	**Rater 2**	**Rater 1**	**Rater 2**	**Rater 1**	**Rater 2**
Observation 1	2	2	1	2	2	1
Observation 2	2	2	2	2	2	2
Observation 3	2	2	1	1	3	3
Observation 4	3	2	1	1	1	1
Observation 5	1	1	2	2	2	2
Observation 6	4	3	3	4	2	2
Observation 7	2	2	4	4	3	4
Observation 8	2	2	1	1	2	2
Observation 9	2	2	1	1	2	2
Total/45	**20**	**18**	**16**	**18**	**19**	**19**

Inter-rater reliability analysis was performed using Kappa statistics. The results were showed below at Table 6.

Table 6: Inter-rater reliability analysis and Kappa statistics

		Value	**Std. Error[a]**	**Approx. T[b]**	**Approx. Sig.**
Measure of Agreement	Kappa	,673	,178	3,575	,000
N of Valid Cases		9			

The interrater reliability for the raters was found to be Kappa = 0.673 (p <.0.001). Landis and Koch (1977) stated that values of Kappa from 0.40 to 0.59 are considered as moderate agreement, 0.60 to 0.79 substantial, and 0.80 outstanding agreement. That is, the results showed that there is a substantial agreement between raters.

5. Discussion and Conclusion

The purpose of current study was to investigate whether PSTs are Homo Semioticus or not by examining their representational competencies through observation checklist, field notes, PSTs' generated presentations, and multimodal literacy survey data. Preceding data analysis of multimodal literacy survey illustrated that PSTs supposes that they are Homo Semioticus theoretically. For example, findings of this scale dimensions showed that mean of sense-making category was found as 3,65 over 5, for expression category it was found as 4, 24 and for preferring category it was found as 1,81 (it can be considered as 4,19 over 5). However, their artefacts, observers' checklists and field notes revealed that they are not. For instance, of the 89 presentations, only 37% include non-text representations in order to foster meaning making with using multiple representations. In all presentations, 60 have two types, 29 have three types of representations.

PSTs are living in a contemporary and digital era which is surrounded by numerous signs and devastating communication tools. In other words, they are surrounded by countless textual, non-textual, verbal, or non-verbal signs or texts introduce particular meanings in social or private spaces. Science classroom is also a social space where teaching and learning activities are executed through a dynamic and reciprocal communication. The extent of how intended meanings or messages obtained through the communication can be seen as a measure of success of instructional aims. At this point, social semiotics proposes that each sign or source pose a meaning that is socially given and to communicate the intended meaning appropriate signs and semiotic sources should be provided. The term 'semiotic resource' is therefore a key term in social semiotics. It originated in the work of Halliday who argued that the grammar of a language is not a code, not a set of rules for producing correct sentences, but a 'resource for making meanings' (1978: 192). Homo Semioticus is a human being who may make meaning of particular discourses and who may design a discourse that should serve the message in convenient ways. The context of this study embraces a stance according to which PSTs should design communication ways that can facilitate affordances for learning of science content. The increasing multimodal density of contemporary texts present a challenge for the users, who need to become familiar with the "grammar" of different modes (Kress and van Leeuwen, 2006; Mackey and Shane, 2012), and develop an explicit knowledge of the different semiotic codes, beyond traditional comprehension strategies developed for typographical texts (Leu, 2013).

In science education, there are a lot of teaching and learning processes in which students make their own-meaning of the content throughout listening, reading, watching, seeing, experimenting, discussing, or exercising. All of the actions above aim

to create a meaning and so built personal knowledge, conception, understanding (Townsend, Brock, and Morrison, 2018). Additionally, the tools which carry messages of communication between people and the nature evolves and changes due to technological progress and changes social life habits. This situation has some implications to teachers. Firstly the importance of meaning making in instructional activities and secondly the evolutionary changes in communicational ways that directed by technological developments are the points that a teacher should be aware of and master (The London Group, 1996). In this context, this study considered the importance of multimodal and semiotics sources in science teaching and learning processes and how PSTs think, benefit, and use them to be called as homo semioticus who understands the roles of semiotic and multimodal resources to promote meaning making in a socio-semiotic context. In other words, in order to understand and communicate the language of science, how PSTs integrate multimodality into their presentations, instructions, or expressions during their educational career to be a science teacher. Brandstetter et al (2018) expressed that one of the requirements of scientific literacy is to have an ability to "read visual forms of representations" and see understanding.

Being literate in science and engineering requires the ability to read and understand their literatures (Norris and Phillips, 2003). In today's world understanding visual forms of representation is increasingly important. Learning materials, paper based and virtual media, heavily rely on these forms of representation (Treagust and Tsui, 2013). In order to be able to support students' understanding of visual representations through effective learning materials, more research about specific strategies of pictorial processing is needed (Schnotz et al., 2014). In this regard, representational competence, an aspect of visual literacy that includes making decision about appropriate types and uses of representations as well as the ability to interpret, transform, and produce visual representations to conceptualize and communicate about science concepts, is a key component of science literacy (Kozma and Russell, 2005; Nitz, Ainsworth, Nerdel, and Prechtl, 2014; Tippett, 2018)

As it was stated before by the expression of Anstey and Bull (2006), multimodal literate person is able to benefit all modes of communication. Qualitative findings of this study showed that, in practice, almost all of instructions were executed through use of a few multimodal sources among which text mode was dominant and multimodality was not observed. Furthermore, there observed no interrelationship between those modes, therefore, they were nonintentional. On the other side, multimodal literacy questionnaire result indicated that almost all of participants are multimodal literate. They implicated that participants opt to use semiotic sources and multimodality for meaning making. However, the data about classroom interactions demonstrated a few classroom interactions due to multimodal tool in the classroom. Furthermore, although the results of questionnaire displayed that participants recognize the importance of using multimodality for an effective social communications during instructions, they did not show any effort to promote social interactions to promote meaning making. PSTs dominantly used iconic/symbolic representations (79%) in their artefacts. It can be

said that participants showed an emotional approach as they respond the questionnaire without they have theoretical knowledge and awareness for implication for instruction. Multidisciplinary character of science teaching situates a lot of information and knowledge systems in various forms such as visual, mathematical, narrative or integration of them (Lemke, 1998). Therefore, a science teacher is expected to be aware and able to understand those components of language of science and teach them in meaningful ways. Another crucial thing is, as the New London Group (1996) emphasized, is use of technology in science classes, because technology offers various and effective means to use multimodality in classroom circumstances. Armstrong et al. (2005) conducted a collaborative study through which they observed the use of interactive whiteboard (IWB) technology by three teachers during their instructions and the effect of ways they use the IWB on the classroom interactions. They found that technology offered many facilities that needs use of multiliteracies and without abilities and specific theoretical knowledge those technologies were used as similar to classical boards. What is more, classrooms where teachers are able to understand the language of technology were better to build effective classroom interactions to promote meaning-making. Their study's findings have similarities with present study. In this study, although the participants benefitted and used technology, classroom interactions were like classical and teacher centered. In other words, the use of technology during instructions does not merely mean just putting the devices or tools into the classroom and turning them on.

Those findings and considerations shed a light on the gap between theoretical awareness and practical implications of pre-service science teacher about multimodal and semiotic literacy. A strong possible reason of this gap can be that the participants have no systematic and theoretical knowledge about multimodality and meaning-making in science education. In the classrooms, preparation of content presentation could imply how they aware and sophisticated about multimodality without having any experience. In other words, the ways in which they present and build classroom interactions showed their theoretical awareness about multimodality and meaning-making in instruction and problems in practice is another factor that could need to be experienced. This factor can be taken into account after they have satisfactory education about multimodal and semiotic literacy. Finally, this gap demonstrates that participant pre-service science teachers cannot be called as "Homo Semioticus" although they think themselves as multimodal literate. To call them as like that, there could be course or series of courses with theoretical knowledge and practical experience. This issue is crucial in science education because without understanding the language of science and presenting content in its characteristic language, it seems very difficult make meaning in science lessons, especially in the digital era we live in when communication ways and tools increased and evolved thanks to improvements in technology and when socio-cultural diversity increased globally.

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Appendix 1: Questionnaire Items and Functions

I am not agree I agree
1 2 3 4 5

Item		Description	Category
1.	I prepare an interactive presentation of content comprising elements like music, visuals and animations.	This item explores the views about use of interactive multimodal resources during a classroom presentation.	Expression
2.	I benefit from visuals like graphics, pictures, and images in my texts.	This item explores the views about use of semiotic resources in texts.	
3.	I feel good to express my opinions through an entity that integrated of texts, sound, and image.	This item explores the views about use of semiotic resources during a discourse.	
4.	I organize my ideas systematically thanks to various visual components (table, graphics etc.)	This item explores the beliefs about integrative and systematizing factor of multimodal resources.	
5.	Various components in my presentations (music, visual etc.) promotes meaning making.	This item explores the views about use of multimodal tools for meaning making.	
6.	I can determine reliability of content in various media (newspaper, TV, social media etc.)	This item explores the views about the function of semiotic resources to get appropriate meaning.	Sensemaking
7.	I regard the gesture of somebody when I listen.	This item explores the views about the function of body language during a discourse.	
8.	I recognize how visual, auditory, and textual effect individuals.	This item explores the views about how individuals reflect multimodal tools.	
9.	I associate visual and verbal information belonging to different media tools.	This item explores the views about the association of meaning making tools from different sources.	
10.	I interpret the integrated information that collected from many sources.	This item explores the views about how individuals generate a sole meaning from different multimodal sources tools.	
11.	I associate the information I reached through visual and auditory tools.	This item explores the views about how visual and auditory sources make meaning mutually.	
12.	I use a body language appropriate to the words while I am speaking.	This item explores the views about how body language is a meaning making in a discourse.	Prefering
13.	I do not like efforting to interpret images, audios, and graphics simultaneously.	This item explores the views about whether individuals have a tendency to avoid interpreting of multidimensions of meaning making.	
14.	I get bored of communications comprising of texts, audio, visual components.	This item explores the views about how approach multimodal sources.	
15.	Electronic media in which visual, auditory and textual components distract.	This item explores the views revealing whether electronic multimodal tools have distracting effect.	
16.	Integrating and benefiting visual, auditory, and textual components may	This item explores the views about whether multimodal sources cause	

	lead thoughtfulness.	thoughtfulness in people's mind.
17.	When I express myself, I believe the power of words.	This item explores the views how people consider components of a self-expression.

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