REPUBLIC OF TURKEY

YILDIZ TECHNICAL UNIVERSITY

GRADUATE SCHOOL OF SCIENCE AND ENGINEERING

DEVELOPMENT OF THE MULTIMODAL TEXT DESIGN TRAINING MODEL FOR SCIENCE TEACHERS OF GIFTED STUDENTS: AN EDUCATIONAL DESIGN RESEARCH

Zekai AYIK

DOCTOR OF PHILOSOPHY THESIS

Department of Mathematics and Science Education

Science Education Program

Supervisor

Prof. Dr. Bayram COŞTU

July, 2021

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A thesis submitted by Zekai AYIK in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY is approved by the committee on 30.07.2021 in Department of Mathematics and Science Education, Science Education Program.

Prof. Dr. Bayram COŞTU

Yıldız Technical University

Supervisor

Approved By the Examining Committee

Prof. Dr. Bayram COŞTU, Supervisor
Yıldız Technical University

Prof. Dr. Hakan AKÇAY, Member
Yıldız Technical University

Prof. Dr. Emine ADADAN, Member
Boğaziçi University

Assist. Prof. Dr. Gülbin ÖZKAN, Member
Yıldız Technical University

Prof. Dr. Funda Savaşçı AÇIKALIN, Member

Istanbul University-Cerrahpaşa

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Zekai AYIK

Signature

Dedicated to Kübra

ACKNOWLEDGEMENTS

In this tough, enjoyable, and long journey there are many people that I want to thank. First, I would like to thank my supevisor, Bayram Coştu, for providing valuable feedbacks and support throughout my graduate school career. Second, my special thanks go to Emine Adadan for her vital feedbacks, supports, and patience during the research. I also thank Hakan Akçay for his valuable recommendations and ideas in the progress of the research.

I would also like to thank my dissertation committee members for all of their incredibly helpful advice and feedbacks.

I would also like to my amazing wife, Kubra: you are the most loving and supportive partner anyone could ask for. I would also like to thank to Cecilia De Molinari for supports and recommendations during all phases of research. I would also like to thank to my friend, with whom I paved this way, M. Davut Gül for his supports and valuable ideas.

Finally, I'd like to thank all of my friends and colleagues for their kind help and feedback during my PhD.

Zekai AYIK

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LIST OF ABBREVIATIONS

CHC	Cattell-Horn-Carroll
D	Domain
DIM	Draft Intervention Model
DRA	Disciplinary Relevant Aspect
EDR	Educational Design Research
HLT	Hypothetical Learning Trajectory
IC	Intersemiotic Cohesion
ISM	Intersemiotic Mechanism
ISToG	In-Service Science Teacher of Gifted Students
LT	Learning Trajectory
MDST	Multimodal Didactic Science Text
MMS	Mixed Mode Semiosis
PD-MUST	Professional Program for Multimodal Didactic Science Text Design
SA	Semiotic Adaption
SC	Student Conception
SF-MDA	Systemic Functional Multimodal Discourse Analysis
SFT	Systemic Functional Theory
SM	Semiotic Metaphor
SR	Student Representation
ST	Semiotic Transition
STOP	Semiotic Text Observation Protocol
SX	Semiotic Mixing
TC	Teacher Conception
TP	Thematic Pattern

TR	Teacher Representation
VTL	Variation Theory of Learning

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ABSTRACT

Development of the Multimodal Text Design Training Model for Science Teachers of Gifted Students: An Educational Design Research

Zekai AYIK

Department of Mathematics and Science Education

Doctor of Philosophy Thesis

Supervisor: Prof. Dr. Bayram COŞTU

Meeting the pedagogical needs of gifted students in science classroom requires specific pedagogical strategies and the competencies of teachers. In gifted science classroom, this competency includes designing didactic texts which foster meaning making (internalized learning product) of content and creativity in externalized learning products. Informed by multimodality and social semiotics, this study aims to develop a professional development model (intervention) that will develop multimodal didactic science text design competencies of science teachers of gifted of gifted students. The multimodal didactic science texts are expected to support (1) meaning-making of science content and (2) creativity in learning products. The intervention model has been developed within educational design research methodology. Six experienced in-service science teachers who work in schools of gifted students (BILSEM). Data is continuously gathered by interview data and participant's multimodal text designs. Data analysis was done both qualitatively and quantitatively. The developmental progress of participants' text design competency was the monitor of the development of the training program. The development of intervention model involves a preliminary phase, development phase (prototyping), and evaluation phase. The developed training model consists of design principles and two hypothetical learning trajectories that have their own learning goals, content, learning activities, and assessment tools. Learning activities in a HLT involve awareness, recognize, overt instruction, design, feedback, and re-design activities. In the end of the study, it was observed that the training model for multimodal didactic science texts design significantly improved the design skills of the participant teachers in the expected direction and the program was developed for future implications.

Keywords: Gifted education, multimodality, didactic texts, science education, educational design research

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ÖZET

Özel Yetenekli Öğrencilerin Fen Öğretmenlerinin Multimodal Metin Tasarım Becerilerinin Geliştirilmesi: Bir Eğitim Tasarım Araştırması

Zekai AYIK

Matematik ve Fen Bilimleri Eğitimi Bölümü

Doktora Tezi

Danışman: Prof. Dr. Bayram COŞTU

Fen sınıfında özel yetenekli öğrencilerin pedagojik ihtiyaçlarının karşılanması, belirli pedagojik stratejiler ve öğretmenlerin yeterliklerini gerektirir. Bu yeterlilik, dışsallaştırılmış öğrenme ürünlerinde içerik ve yaratıcılığın anlamlandırılmasını (içselleştirilmiş öğrenme ürünü) besleyen didaktik metinler tasarlamayı içerir. Kuramsal tabanı multimodalite ve sosyal göstergebilime dayanan bu çalışma, özel yetenekli öğrencilerin fen bilimleri öğretmenlerinin multimodal didaktik fen metinleri tasarım yeterliklerini geliştirecek bir eğitim (müdahale) modeli geliştirmeyi amaçlamaktadır. Multimodal didaktik fen metinlerinin (1) fen içeriğinin anlamlandırılmasını ve (2) öğrenme ürünlerinde yaratıcılığı desteklemesi beklenmektedir. Geliştirilen profesyonel gelişim program modeli, eğitim tasarım araştırması metodolojisi içinde geliştirilmiştir. Özel yetenekli öğrencilerin okullarında (BİLSEM) görev yapan altı deneyimli hizmet içi fen bilgisi öğretmeni araştırmaya katılmıştır. Veriler, görüşme verileri ve katılımcının multimodal metin tasarımları ile araştırma süresince toplanmıştır. Veri analizi hem nitel hem de nicel olarak yapılmıştır. Katılımcıların multimodal didaktik fen metni tasarımı yetkinliklerinin gelişimi, eğitim programının gelişiminine paralel olarak izlenmiştir. Müdahale modelinin geliştirilmesi bir ön aşama, geliştirme aşaması ve değerlendirme aşamasını içerir. Geliştirilen profesyonel gelişim programı, tasarım ilkelerinden ve kendi öğrenme hedeflerine, içeriğine, öğrenme etkinliklerine ve değerlendirme araçlarına sahip iki öğrenme yörüngesinden oluşur. Bir öğrenme yörüngesindeki öğrenme faaliyetleri, farkındalık, tanıma, açıktan öğretim, tasarım, geri bildirim ve yeniden tasarım faaliyetlerini içerir. Çalışmanın sonunda, multimodal didaktik fen metinleri tasarımına yönelik eğitim modelinin, katılımcı öğretmenlerin tasarım becerilerini beklenen yönde önemli ölçüde geliştirdiği ve programın ileriye dönük uygulamalar için kullanılabileceği görülmüştür.

Anahtar Kelimeler: Özel yetenekli öğrencilerin eğitimi, multimodalite, öğretici metinler, fen eğitimi, eğitim tasarım araştırması

YILDIZ TEKNİK ÜNİVERSİTESİ

FEN BİLİMLERİ ENSTİTÜSÜ

1
INTRODUCTION

1.1 Literature Review

For the future development of a society, educating gifted students an indispensable task (Besançon, 2013) and science education has a prominent position in this task (Soares, 2016). In this respect, educators need to think about addressing the special needs of gifted students in science classroom. Definition of giftedness plays a crucial role in determining the educational needs of gifted students and the pedagogical competencies of educators. More than one hundred and fifty years of scientific research on the education of gifted students, studies have variously conceptualized giftedness, identified gifted individuals, or developed optimal learning processes. Kaufman and Sternberg (2008) report that there have been developed several models for describing giftedness, and these models figure out important environmental influences, non-intellective variables, learning, training, and practicing which transform basic, genetically determined gifts into specific talents in daily life. For example, Renzulli' (2005) three-ring model views giftedness as an interaction of three elements, including well-above-average ability, creativity, and task commitment. Renzulli (1992)) describes gifted students as the individuals who have high degrees of creative ability and have superior productive capabilities. Furthermore, several studies (i.e. Bailey et al., 2016; Besançon, 2013; Chowdhury, 2016) foregrounded the special importance of science education in fostering the talent development and creativity of gifted students.

Intelligence and creativity are the dominant traits and factors in conceptualizing giftedness and pedagogical needs of gifted students in science classroom. Besançon (2013) proposes that intelligence is conceptualized mainly in three perspectives. The first perspective views intelligence as capacity (Binet & Simon, 1905; Huteau & Lautrey, 1999), the second perspective sees intelligence as a set of different capacities (Gardner, 1983), and the third perspective proposes a system of capacities which is organized in a “hierarchical way” (Carroll, 1993; Schneider &

McGrew, 2012). In definition of giftedness, each perspective of intelligence highlights creativity and creative products, which are considered as a fundamental aspect of giftedness (VanTassel-Baska, 2004, p. 1). Starko (2014, p. 25) notes that the common characteristics in these creative products are “novelty and appropriateness”. While the novelty deals with the new ways of expression of the self or thought, the appropriateness is about the appreciation in a certain context or by a certain community of people or being meaningful in a certain context. In this latter respect, Starko (2014, p. 27) proposes that creativity “criteria are set by the culture and the discipline”. Such an approach looks for what is being seen as creative in a particular context or community and on the creativity is that it is not attributed to only characteristics and features of particular persons or products, but as an interaction among the person, product, and environment (Csikszentmihalyi, 1990). Therefore, the environmental factors are seen as crucial elements for creative learning products in a gifted science classroom. In this respect, Glăveanu's (2013) 5A model of creativity sees creativity as a cognitive and sociocultural phenomenon. Therefore, science classroom learning environment as a socio-cultural environment is a significant factor for addressing pedagogical needs in terms of creativity of gifted students.

Davis et al. (2014, p. 2) remark that gifted learners "are silently paying a price", if the pedagogical needs of gifted students are not met. Similarly, Soares (2016, p. 130) posits that “the unfavorable conditions in classroom may cause lost in academic growth; lost creative potential; and sometimes, lost enthusiasm for educational success, eventual professional achievement, and substantial contributions to society". Therefore, the influence of pedagogy followed in gifted classroom is substantial on the learning of the scientific knowledge and creativity of the gifted students. Besançon (2013) Besançon (2013) explores the effect of children, the teaching methods, and the teacher on the development of creativity and creative capacity. In this respect, Chowdhury (2016) remarks that the pedagogical needs of gifted students are not understood widely. He adds that this unaddressed issue become more serious in disciplinary education fields such as science education. Many teachers of gifted students have challenges for meeting the pedagogical needs in gifted classroom.

In addressing pedagogical needs of gifted students in science classroom, the focus of science education should be foregrounded. Regarding the focus of science education, Bailey et al. (2016) posit that teaching of science often realized as to focus on giving content or domain knowledge and expecting students to memorize facts and formulas that relate to the natural world. They note that the contemporary approaches in gifted science education focuses on helping students produce the scientific knowledge as the products of scientific inquiry conducted in science classroom. In some countries, in order to address pedagogical needs of gifted students for science education, special curricula are developed. For example, in Turkey, there have been developed a new science curriculum (MEB, 2019), which is qualitatively different regarding three dimension in pedagogical processes. These dimensions are content, process, and learning products. Furthermore, science education has undergone a shift from teaching decontextualized content to focusing on the role science plays in people's lives as social beings. This shift is reflected on the level of both the syllabi –contextualizing science as a cultural practice—and didactics, by adopting a constructivist approach that assigns a much more active role to the student and recognizes interactions as a central component of science learning. There is an increasing research interest in both the challenges and opportunities learners face in trying to represent scientific understanding, processes, and reasoning. In this respect, there has been a strong research interest in the linkages between science activity, meaning making processes of students, and representational choices/practices that support learning of science.

In order to understand the pedagogical needs of gifted students in science classroom, firstly the conceptualization of learning or the approach for learning should be envisaged. Vygotsky's (1978) sociocultural and activity theories see learning and development as a mediated process. Daniels (2001, p. 1) explain the concepts of "socioculturual" and "activity". It is noted that, in the former, the focus is on "semiotic mediation with a particular emphasis on speech". In the latter, the focus is on "activity itself which takes the center stage in the analysis". Both theories explain and "provide methodological tools for investigating learning processes by which social, cultural and historical factors shape "human functioning". According to Ivić (1989) Ivić, Vygotskian view of learning do not stress the transmission and acquisition of an amount, body or piece of information solely. What he was concerned is “the provision through education, of the tools, techniques and intellectual operations that would facilitate development” (Daniels, 2001, p. 98). In this respect, Wertsch and Stone (1985) view learning as a construction rather than a process of direct transmission or copying and claim that, for an individual, learning depends on the mastery of the cultural system of symbolic representation.

In this respect, learning activities in science classroom can be considered as “practical cultural activities” (Daniels, 2001, p. 75) and the meaning is exchanged through semiotic means or “mediating tools". This exchange is not direct transmission and explained by internalization and externalization concepts (Shepardson & Britsch, 2015; Vygotsky, 1978). According to Engeström and Miettinen (1999), internalization is related to “reproduction of culture” and externalization is the process where the creation of artefacts take place to “transform the culture” which is considered as a human creation. For science classroom, this can be seen as the student production or design of learning products such as designing a diagram, drawing a model, or creating a portfolio.

In the internalization process, the availability of cultural artefacts/tools, which mediate meaning and shape the internalized product of sociocultural activity plays a key role. This can be interpreted as the mediating tools such as semiotic resources mediate meaning. The internalization of this meaning in the classroom as a social context is highly affected by these mediating tools. Vygotsky (1978) remarks the importance of language development for how the development in concept learning take place. However, he did not provide any theory account how language or other semiotic resource systems to account for how meanings are constructed and realized (Tang et al., 2011). Halliday's (2000) systemic functional theory provides powerful insights about how meaning are made through choices from semiotic systems in a social context. Tang et al.(2011, p. 1779) posit that within the ideas of Vygotskian view of cognition, thinking can be seen as “semiotic processes that enact the meaning making practices of a community through various modalities. In this line, (Jewitt et al., 2001) proposes that learning is a process in which students are actively engaged “remaking” information in the forms of complex signs that teachers communicate in the learning environment. In this respect, they posit that learning is seen as a transformational process where students re-conxtualized and re-construct the available resources in science classroom as internalized and externalized products. In sum, learning is considered to involve internalization and externalization processes. In internalization processes, students make meaning of the content through the existence of semiotic mediating tools in science classroom. The externalization process involves students' learning products such which are inevitably shaped by the available semiotic mediating tools in learning environment.

Gagne's (2009) Differentiated Model of Giftedness and Talent involves following factors. These are natural abilities (gifts), environmental factors, intrapersonal factors, the developmental process, and competencies (talents). The natural abilities are given with the child while talents are performance yielding a product such as "memory, inventiveness, leadership, proprioception, endurance and agility" (Margrain, 2011). Therefore, the environmental factors influence the performance and products performed by gifted students. In gifted science classroom, the representations used by the teacher during instruction are crucial part of the learning environment (Ainsworth, 2006; Danielsson, 2016). Regarding learning process in an inter-individual perspective, knowledge is demonstrated through representations (Wartofsky, 1979), and employing right representation fosters learning of scientific knowledge (Ainsworth, 2006). Therefore, as stated above, the representational practices taking place in science classroom affect the internalized and externalized learning products. In other words, the available mediating tools provided in representational practices affect students' access to scientific knowledge and the ways in which they transform the meaning into creative learning products. Liu and Owyong (2011) note that this can be a basis for researching how to make scientific knowledge accessible for student and improve pedagogical transmission. Accordingly, Waldrip et al. (2010) state that the representational practices in science classroom involves teacher conception, teacher representation, student conception, and student representation. Teacher's conception and representational practice affect student conception and student representation that can be viewed as internalization and externalization. In this respect, representations used in science classroom environment are the mediating tools that are, for example, language, visual images, graphics, mathematical symbols, tools, or models etc. used in science classroom. These representations are expected to provide affordances for student conceptions and student representations.

According to claims demonstrated so far, pedagogical needs of gifted students in science classroom involve effective semiotic mediating tools that can enhance internalization (meaning making) and externalization (creative learning products) of science content. Science teachers' competencies of designing effective semiotic mediating tools, such as didactic texts, play crucial role in addressing such a pedagogical need in gifted science classroom. In other words, the didactic science texts as semiotic mediating tools provided by science teacher in the learning environment of science classroom are expected to provide affordances for meaning making of content creative learning products.

The didactic texts as external representations are mediating tools between scientific knowledge and students, and the visual representations use in science classroom are crucial elements for science teaching and learning (Eilam et al., 2014). Teacher representations involve didactic texts that are viewed as fundamental mediating tools in the representational practices in science classroom (Ainsworth, 2006; Danielsson, 2016). Similarly, Mammino (2008) and Gunel and Yesildag-Hasancebi (2016) posit that external representations are vital instruments in science learning and teaching. Didactic texts as the external representations provided to students have great effect on the construction of mental images or internal representation (Mammino, 2008). The internalized structure is seen as mental images or internal representation. In this respect, Harre (1970, p. 180) notes that student learning may be impeded in the case where appropriate internal representation or mental images in the minds of students. According to Mammino (2008), in learning of scientific knowledge, representations or modes other than language can employ complementary role in explanations and descriptions of concepts. Second, the external representations can provide "additional routes for communication and interactions that have the great advantages of immediateness". Third, an external representation can make invisible and abstract entities, concepts, or phenomena more concrete or familiarized. Fourth, the external representations are crucial elements for the construction of students' mental images or internalization. For example, Ainsworth (2008) proposes that the external representations including diagrams, graphs and equations provide affordances for learning of science concepts. The external representations have complementary roles, constrain interpretations, and construct deeper understanding. Parallel to Teo et al,'s (2016) use of concept of affordance, the instructional or didactic text designs can be designed to enhance "usefulness" of a didactic text to increase affordance in a way that gifted students "perceive" information and scientific knowledge. In this respect, while the didactic texts mediate scientific knowledge in science classroom, they play key roles in construction of internalized and externalized learning products. Parallel to the affordance element in 5A model of creativity (Glăveanu, 2013), these texts can provide affordances for creative internalized and externalized product. In this respect, this study focuses on the design and presentation of didactic science texts that support creative learning products for gifted students.

Waldrip et al. (2010, p. 66) remark that the discipline of science should be understood "historically as the development and integration of multimodal discourses" and "where different modes serve different needs in relation to reasoning and recording scientific inquiry." In this respect, Lemke (1998) proposes that the communication of scientific knowledge involves more than language and it is multimodal. In science classroom, the communication of scientific knowledge involves representations such as texts, symbols, numbers, and various visuals. Furthermore, discourses and interactions constructed pose a big potential for that way of communication. The knowledge is presented in a multimodal learning environment. Therefore, didactic science texts are multimodal in nature. In such a learning space, teachers are considered as "designers" of instruction and learning processes (Selander, 2008). As such, since the science texts are multimodal, science teachers are expected have multimodal text design competency in order to provide effective didactic texts as semiotic mediating tools that address internalization and externalization.

Meaning in didactic science texts are realized trough semiotic resources as sign systems within certain modalities those take part in creation of pedagogical discourse (Bernstein, 2003) of science classroom. In this respect, this study investigates didactic multimodal science texts (hereafter MDSTs) where language, visual imagery, mathematical modes are complemented for the semiotic construction of scientific knowledge (O'Halloran, 2007). It is hypothesized that if design of these texts is addressed within a conscious deployment of those modalities and emerging semiotic resources, meaning making and communication may be enhanced during learning activities. In this respects, MDST design competencies of science teachers of gifted students emerge as an important issue in enhancing meaning making of content and creativity in learning products designed by gifted students. Science teachers are expected to provide rich semiotic resources of knowledge and orchestrate a multimodal teaching performance that is compromised of well-design system of information (Selander, 2008). Ainsworth (2006) asserts that those ways to "design multi-representational systems influence the processes and outcomes of learning". The term representational competency refers to instantiation level of well-designed sign system of information (DiSessa, 2004). The main criteria to determine and evaluate representational competency in teaching performance consist of representational competency progress criteria of DiSessa, 2004 (p. 1). The first criterion involves inventing or designing new representations. The second one, representational competent teachers are expected to "critique and compare the adequacy of representations and judge their suitability for various tasks". The third one, representational competency involves understanding "the purposes of representations generally and contexts and understand how representations do the work they do for us". The fourth one, representational competency involves the ability to articulate representations' competence in providing affordances for meaning making. Finally, representational competency requires learning new representations "quickly and with minimal instruction".

Since the instructional or didactic texts have a prominent place in learning of scientific knowledge and concepts, the design and preparation of instructional texts require high level of pedagogical content knowledge, therefore teachers need to be specifically trained (Kulgemeyer, 2018). In this respect, parallel to Harre (1970) and Herrlinger et al. (2017), poor designed didactic texts may impede learning. In this respect, the designed representations affect both learning processes and learning products (Ainsworth, 2006). This study focuses on the MDTS design competencies of in-service science teachers of gifted students (hereafter ISToG). This text design competency requires representational competency, and the science texts are multimodal in nature. Therefore, the focus is narrowed into the multimodal science text design competencies.

In the relevant literature, numerous studies (i.e Adadan, 2013; Ainsworth, 2006; Jaipal, 2010; Jewitt et al., 2001; McDermott & Hand, 2013; Meneses et al., 2018; Murcia, 2010; Nam & Cho, 2016; Wu & Puntambekar, 2012; Yeo & Nielsen, 2020) investigated the role and effect of multiple representations and multimodal texts on learning of scientific knowledge. For example, Nam and Cho (2016) and Yeo and Nielsen (2020) point out that the representations used in science classroom contributes to conceptual learning and enhance students' abilities to communicate scientific knowledge. Furthermore, several studies (i.e. Gebre & Polman, 2016; Tang et al., 2019; Teo et al., 2016) explored the impacts of student designs of multimodal representations on student understanding of scientific knowledge. The studies generally demonstrate that teachers' employment of multiple and multimodal representations enhance learning of science and designing multimodal learning products. The studies also demonstrate that the use of multimodal representations in science classrooms fosters learning of science since these representations increases the meaning making potentials of communication of scientific knowledge. However, as Airey and Linder (2009) proposed, the use of these representations should be in a conscious manner to succeed high meaning making potentials.

In order to understand science teachers' representational practices, Patron et al. (2017) investigated the chemistry teachers' reasoning behind the visual practices in teaching chemical bonding. The focus was on how the scientific knowledge is made accessible by the representations used by chemistry teachers. The study demonstrated that teachers do not have consistent pedagogical reasoning behind preferences in using visual representations and the deployment of scientific representations are mostly based on trial and error. Similarly, Danielsson (2016) investigated the science teachers' representational practices regarding how science teachers employ speech, visual representations, gaze, and proxemics to realize processes taking place in the content. The data is quantitatively analyzed, and it was revealed that the observed science teachers employ all of these modes for to demonstrate distinct aspects of the processes content. This finding is quite similar to the findings of Airey and Linder (2009) who demonstrate that use of multiple and critical constellation of modes helps to demonstrate different facets of content, and this increases the accessibility of scientific knowledge. Regarding multimodal science text design competencies, Eilam and Gilbert (2014) notice that although science teachers use multimodal representations for demonstrating scientific knowledge, they are not often aware of "the affordances or limitations of different modes of representations". In addition, they remark that science teachers have limited awareness about student challenges in front of different representations. Teachers also should focus on providing the content knowledge and with appropriate representations, which are satisfactory meaning making power or affordances. Likewise, Eilam et al. (2014) highlight the limited awareness of science teachers about the affordances and limitations posed by representations used in science classroom and limited design competencies.

However, the studies on science teachers' competencies in selecting and designing multimodal representations mostly focus on description of uses in practice and no certain set of criteria have been established for effective representations. For example, Danielsson's (2016) study provides good insights into how science teachers employ and use different modes to present scientific knowledge but it does not provide any set of criteria regarding effectiveness of the texts. There is a paucity of researches that provide strategies about how to evaluate the efficiency and meaning making power in multimodal didactic science texts. Jaipal's (2010) and Airey and Linder (2009) study provides a framework on in which ways different modes can be employed to demonstrated different aspects of content, however they do not present a metastrategy to design effective MDSTs. While, DiSessa's (2004) representational competency framework provides good insights about designing effective representations, it does not provide any strategy for designing didactic science texts. Furthermore, the studies to evaluate the efficiency of multimodal representations are mostly based on observation or interview methods. Finally, there is lack of studies on developing a specific development program for fostering science teachers to use or design effective multimodal texts in teaching of science. In this respect, Eilam et al. (2014) remark the need for specialized training or instruction which helps science teachers to develop multimodal text design competency. Given with this background, the rationale of this study engages the absence of (1) a framework including a meta-strategy for designing MDSTs, (2) a framework for evaluation of MDSTs.

1.2 Objective of the Thesis

This study focuses on the didactic texts used in teaching of science in gifted science classroom. Didactic texts are key elements of the mediating tools in the learning environment and have a crucial role in meaning making of scientific knowledge and constructing creative internal and external learning products. In this respect, selecting and designing didactic science texts are seen as important pedagogical competencies of ISToGs to foster learning and understanding. In other words, providing effective text in teaching is seen as main element of the teacher's pedagogical repertoire. ISToGs are expected to be representationally competent. The existing literature has focused on mostly the conceptualization, effectiveness of multimodal texts in science classroom, observation on the multimodal orchestration of teacher during teaching, multimodal analysis of classroom interactions, and ideal multimodal texts for teaching of science. Furthermore, no study was observed on developing such kind of pedagogical competency of ISToGs. In this regard, this study aims to develop and test a professional development program model, called as Professional Development Program for Multimodal Science Text Design Training Program (hereafter PD-MUST), in terms of improving multimodal literacy levels of and multimodal didactic science text competencies of ISToGs.

1.3 Original Contribution

This study aims to contribute existing research field with a novel product, which is a multimodal professional development model for science teachers of gifted learners. This model is based on previous research and theoretically synthesized from different theoretical and conceptual perspectives including learning, meaning making, communication of scientific knowledge, discourse of science, giftedness, creativity, and science education of gifted learners. This professional development program can be further used in pre-service and in-service professional education of science teachers of gifted students. Furthermore, this descriptive and interventionist design research is conducted totally in virtual platforms including several digital learning tools and mediums. Therefore, it also provides a methodological perspectives and practical tools for the future studies that are conducted remote, especially for those that are interventionist and design based.

1.4 Research Questions

How does the professional development program for multimodal didactic science text design with design based and transformative characteristics support multimodal didactic science text design competencies of in-service science teachers of elementary level gifted students?

1. What are the prior MDST text design competency levels of in-service science teachers of elementary level gifted students before the implementation of professional development program for multimodal didactic science text design?
2. What is a teaching-learning strategy that would help in-service science teachers of elementary level gifted students to achieve these goals?
3. How (well) is professional development program for multimodal text design (design) implemented?
4. What are the effects/results of implementing professional development program for multimodal text design (design)?

1.5 Limitations and Assumptions of the Study

The product of this study is developed within virtual platforms and remote in the Covid-19 pandemic situations where physical interactions and share of physical environments are impossible. The learning and design activities, instructions, and meetings were done remote. The best application of the study should be blended type of learning which involves both the affordances of digital platforms and design tools, and the opportunities of physical learning environments such as group works and instant scaffolding in the designs. Secondly, participants are in-service science teachers and faces some difficulties for sharing time for the design activities. This situation causes delays in completing of design assignments and delays in the schedule of the implementation program. This situation also gave birth to some lose of concentration for those who completed in due time. Therefore, if the participants can share enough time or the study is implemented in a time gap and an environment where they can have a complete focus and share of time, the implementation of the study can be easier and more effective. Third, the study was conducted with participation of science teachers working with six, seven, and eight grade level gifted students. Teachers from other levels, such as teachers of high school level gifted learners could be participated. This issue important, since the design of multimodal science texts including more abstract and complex science content.

The first assumption of this study involves that participants have similar backgrounds of teaching experience, content knowledge and pedagogical content knowledge. Second assumption is that, during the data collection, the participants give honest and accurate responses to the directed questions. Third assumption involves that the participants are not affected from each other in the virtual environments, and they do not share their responses or text designs. Final assumption is that participants shared enough time for the completion of learning tasks.

2
THEORETICAL FRAMEWORK

As stated earlier, this design research aims to develop an intervention model (PD-MUST) which goals to foster ISToGs' MDST design competencies. The study is both theory driven and data driven. The theory driven side involves (1) the conceptualization, design, and analysis frameworks for MDSTs and (2) draft form of PD-MUST. The data driven side involves the development of draft PD-MUST within iterative cyclic design experiments. Firstly, theoretical background for MDST concept involves how meaning making processes take place through representational practices in science classroom, how meaning is realized regarding form and function of texts, the multimodal nature of meaning making through didactic science texts, and the pedagogical aspects of didactic texts. In this respect, the theoretical lenses are social semiotics (Halliday, 1978; Hodge & Kress, 1988; Lemke, 1990) , multimodality (Jewitt et al., 2016; Kress, 2010) systemic functional theory (Halliday, 2004), and variation theory of learning (Marton & Tsui, 2004). This theoretical backdrop informs conceptualization, design, and evaluation of MDSTs. Secondly, for the development of the PD-MUST, this study embraces a theoretical background for the pedagogical approach of learning activities in which ISToGs take part. The theoretical framework for pedagogical approach of PD-MUST involves learning by design approach of (Cope & Kalantzis, 2015) and revised Bloom's taxonomy (Anderson & Krathwoll, 2001) for learning goals.

2.1 Theoretical Framework for Conceptualization and Design of MDSTs.

The theories that guide and inform the MDST design are visualized in the Figure 2.1 below. The figure summarizes what the mentioned theories provides for conceptualization of MDSTs. In the following parts, each of theoretical lenses are explained and, in the end, the resultant frameworks for conceptualization of MDST and MDST design.

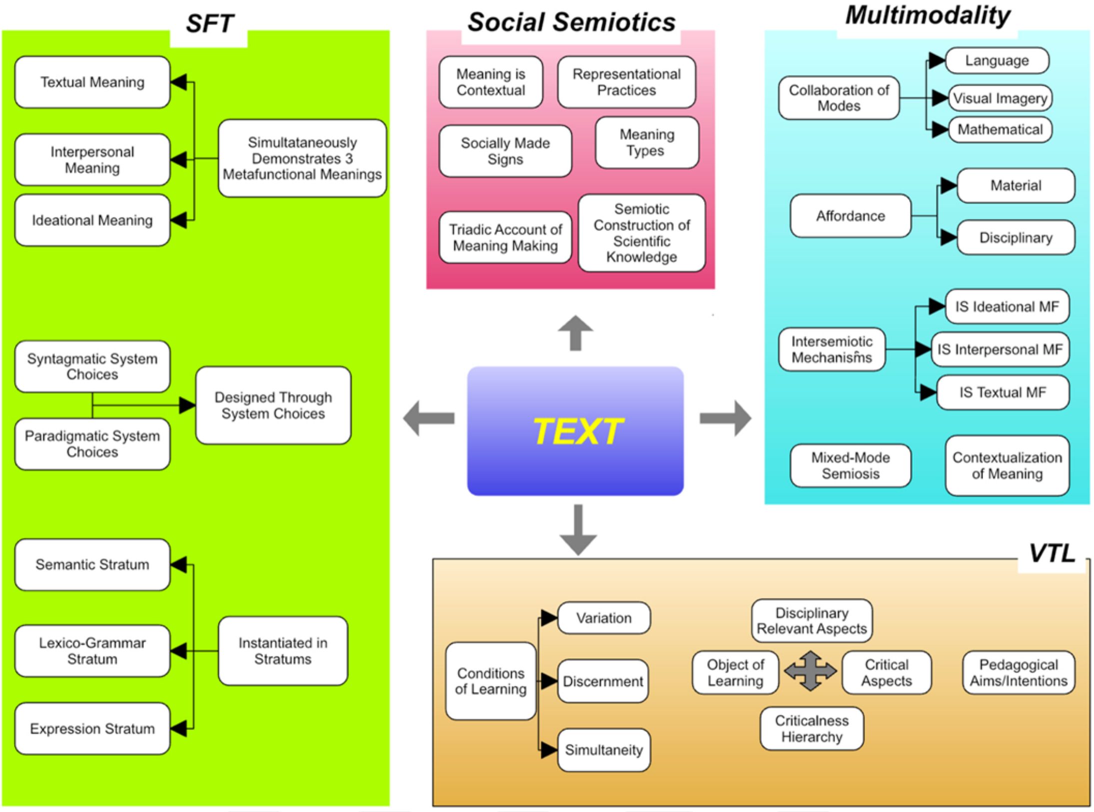

Figure 2.1 Theoretical backdrop informing conceptualization of MDST

2.1.1 Social Semiotics

Social semiotics informs meaning making and sign making processes in representational practices taking place in gifted science classroom, meaning types of signs residing in MDSTs, and the place of MDSTs in representational practices of science classroom. Social semiotics is a post-structural theory, which investigates meaning making processes (semiosis) in social actions (Lemke, 1990). In this study, it provides insights how meaning making take place by the use of didactic texts in social classroom environment and described as a study of socially-based sign systems that function as communicative resources for meaning making in a particular culture (O'Halloran, 2007). Social semiotics proposes that learning is a communicational and social phenomenon that happens through re-construction and re-contextualization of meaning conveyed by signs or texts. Social semiotic approach posits that meaning is situated and embodied in a community depending on the contexts. According to social semiotics, a meaning is given by a community to a particular action or sign depending on that community's characteristic or specific meaning making practices. Therefore, action of meaning making cannot be considered as isolated of the community and social dynamics (Lemke, 1990, p. 2010).

2.1.1.1 Meaning Making (Semiosis) and the Forms of Semiosis

Different material forms of signs convey meaning. The triadic form of semiosis (see Figure 2.1) of Peirce (1931) explains the meaning making processes as happened trough materials (or mediating tools) that human can perceive any form of perception (Chandler, 2007, p. 13). Semiotic resources are made in the forms of different signs. These signs are categorized into symbols, icons, and indexes. Texts are made of semiotic resources each of which have different meaning making function.

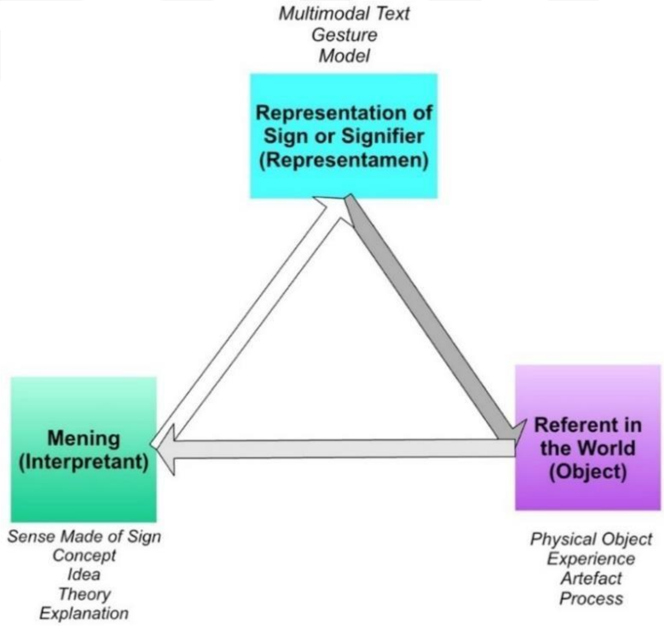

Figure 2.2 Triadic account of meaning making

This framework was based on Peirce's (1931) triadic model for how the process between sign, learning and meaning works. Sign or representation can be verbal, visual, actional, gestural or bodily semiotic sources, a graph, or a table. Texts can be considered as the representational of referent(s) in the world. Content or object of learning may be a physical object, an experience, a scientific process. Meaning or interpretant is the sense made of sign/text, a concept, an idea, a theory, an explanation. Semiotic sources consist of lots of sign in order to form and transmit meaning. Lemke (2003) claims that all disciplinary meaning making practices, including mathematics and science, can be represented by a triadic account of how signs have meaning (see Figure 2.1). Accordingly, the triadic account of meaning making informs the interplay between teacher's science knowledge, the representations (MDSTs) through which teacher's knowledge is presented, and how the students make meaning through the representations.

The triadic model is a typical presentation of meaning making (semiosis) according to semiotic approach. It should be noted that this flow of procedure happens in a social community and product of each reciprocal interplay is distinctive depending on the community because "learners' everyday language is the crucial resource for negotiating understandings of (and between) the three components of the sign system in science" (Waldrip et al., 2010, p. 68). In science classroom, when any piece of scientific knowledge or fact is represented by a text (e.g a graph), the fact is interpreted by students and their own meaning is re-constructed and re-contextualized. Texts or representations are ways or tool to explain object of learning or referent.

In Peirce's model, distinctions are made in science, or any other field, between a signifier, interpretation, and the referent. Representations in signs or signifier (e.g., a charts depiction of density), the interpretation or sense made of this sign by the interpreter (the scientific idea of density), and its referent, or the phenomena to which both the interpretation and signifier refer (examples of the operation of energy on objects in the world). Signs are not arbitrary, signs are motivated and transformative (Fredlund, 2015). The signs used in classroom have implications for thinking about learning. First, students' signs are never (more or less competent) "repetitions, reproductions, copies", of the teacher's sign: the students' signs are always transformations of the resources that were available to them, made in the light of their interest at the point of making the sign (Tang et al., 2019). Second, this concept of sign shifts the focus from sign system to sign making. In doing so, it challenges the notion of sign making as a matter of the sign maker's competence or representational competency to suggest that sign making is a matter of the design of meaning. Halliday (2004) posits that every sign serves three functions simultaneously. They express something about the world (ideational meta-function), position people in relation to each other (interpersonal meta-function) and form connections with other signs to produce coherent text (textual meta-function)". This proposition will be extensively handled in the following parts.

Viewing signs or texts as motivated and always transformative leads signs to be understood as a trace of the designed interests of the situated learner or sign maker. In other words, sign is not an entity or idea that is directly transmitted to learner, it is represented and reconstructed and re-contextualized by learners according to semiotic dynamics (such as learner interests) and potentials (such as previous representational practices) of learners. In learning, this can be a point of view why learning varied although same learning sources and activities are given by same teacher, as stated by Jewitt et al. (2001). This challenges the view of learning as acquiring competence, and suggests that learning is a process of multimodal design. At the end of sign making, students attain external representations. This implies that all attempts by learners to understand or explain concepts in science entail representational work in which they have to use their current cognitive and representational resources (internal representations) to make sense of science concepts that are new to them, and that are reiterated in new representations that must be freshly interpreted (Waldrip et al., 2010). Representations are designed by different modes, and modes include various signs to transmit meaning and to realize learning.

2.1.1.2 Meaning Types

In this part, the meaning types produced by semiotic resources/signs in MDSTs are handled. The meaning types conveyed by a sign or semiotic resource in a mode (i.e language, visual image, or mathematic mode) affect the emergent meaning and meaning making. Lemke (2000) conceptualizes the meaning types that are represented by semiotic resources. The meanings represented by signs or semiotic resources are categorized in a meta-approach to for better conceptualization of meaning. Accordingly, there exists two kinds of meaning realized by the modes in a MDST. The first meaning type is the typological meaning, which involves categorical meaning types. According to Ivry and Robertson (1998) the representations that demonstrate categorical meaning are important for object recognition. In this respect, typological meaning types help to categorize the referents and allows to construction of information pieces and knowledge. Further categorization for this meaning type is made as binary categorizations (two-fold) and taxonomic distinctions. Discrete variation happens in typological meaning.

Second meaning type is stated as topological meaning which involves continuity in different qualities or an assemblage of different qualities" where "experientially simple, specifying values along a single dimension or scale along which quality varies". In this meaning type, continuous variation take place within the meaning. The representations used for demonstrating spatial relations involve coordinate representations, which functions to locate objects in space and calculate the space between those objects (Ivry & Robertson, 1998).

2.1.1.3 Representational Practices in Science Classroom and Teachers' Roles and Competency

This part explains how the semiotic mediating tools or resources including teachers' didactic texts play role in representational practices and how they affect student meaning making and student's learning products. Roberts's (1996, p.423) trialogue and Andersen and Munksby's (2018) didactic model propose a reciprocal linkage between teacher, student and domain (content). The arrow from teacher to student indicates the accepted wisdom of representations, as communicated by the teacher, while the reverse arrow indicates the students' prior or developing representations of the domain (see Figure 2.3). Waldrip et al. (2010) adapted Roberts's (1996) model of pedagogy and Peirce's (1931) triadic model and they called it as IF-SO (Identify-Form/Function-Sequence- Ongoing Assessment) framework. It can be understood as a set of interlocking triads (see Figure 2.4). From this perspective, teaching and learning in science engages various triads incorporating the domain

(D) (scientific knowledge), teacher conceptions (TC), teacher representations (TR), student conceptions (SC), and student representations (SR), where all are reciprocally supportive. At all stages in the learning process, the teacher must rely on interpreting students' representations as evidence of their understanding.

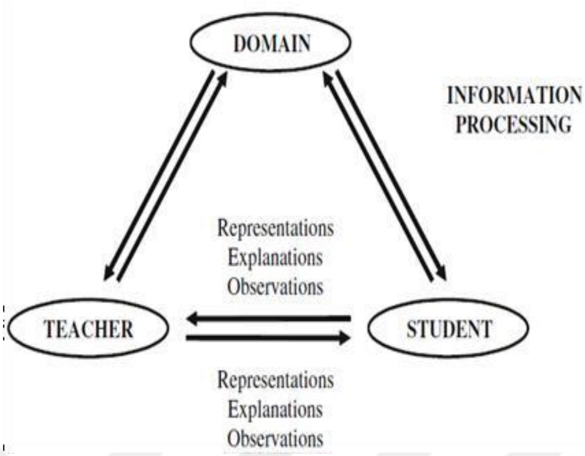

Figure 2.3 Trialogue of ınformation processing in classroom

This model is based on the theoretical background that defines the roles an competencies of teachers in teaching and learning activities and defines teacher-student and student-student interactions. Regarding the MDSTs used in the science classroom, the roles and competency of teacher can be observed in the Figure 2.4 below.

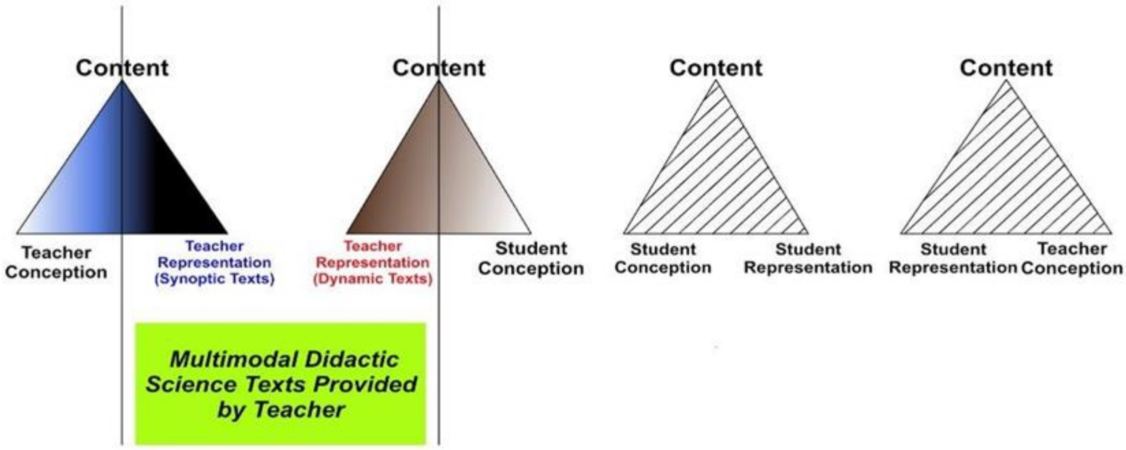

Figure 2.4 Representational practices in science classroom and place of didactic texts

2.1.2 Multimodality

2.1.2.1 The Multiplicity of Semiotic Resources

Researches on the meaning making processes in science classroom were dominantly conducted in logocentric view, which gives language as a privileged position in meaning making and construction of scientific knowledge (Fredlund, 2015; Jewitt, 2008; K. S. Tang et al., 2019; Tippett, 2016). But the semiotic construction of scientific knowledge and analysis of meaning making of scientific knowledge in pedagogic practices need go beyond of logocentric view, since discourse of science is inherently multimodal (Halliday & Martin, 1993). Multimodality proposes that meaning take place through collaboration of more than one mode (e.g. language, visual imagery, mathematical symbolism, gesture, etc.), not due to an isolated single mode. Therefore, in order for understanding how meaning is realized, one needs to focus on the collaboration between the participating modes (Lim, 2011). In this study, multimodality deals with the use of different semiotic resources for meaning making as well as the ways in which these different semiotic resources combined to make meaning in a MDST. What is more, multimodality is a field of application, which helps to recognize the differences among different semiotic resources in both analyzing and creating meaning (Jewitt et al., 2016).

It seems quite difficult to define the concept of mode since it has both semiotic and material aspects (Bateman et al., 2017, p. 113). Bateman et al. (2017, p. 115) propose that "a semiotic mode may also define particular ways of combining its signs or sign parts so that specific meanings may be recovered or evoked". In this respect, a mode can be expressed in two approaches, which are (1) lexical approach where signs simply associate form and meaning and (2) grammatical approach where complex signs exist in a lexicogrammatical structure to produce meaning. "The grammatically-organized semiotic resources place their distinguishable signs within a productive system of meaning potential" (Bateman et al., 2017, p. 113). From a multimodal perspective a wide range of modes are considered as contributing to learning (including gaze, gesture, movement, body posture, spatial location, image, speech, music, sound-effect, and so on). It follows then that all modes have the potential to support and contribute to classroom learning. In other words, learning is not seen as a primarily linguistic "accomplishment" and the range of modes need to be included in the analysis of learning (Lim, 2011).

This theorization implies that each mode in MDST during communication of scientific knowledge has different material and social affordances for teaching and learning. These "modal affordances" represent or shape curriculum knowledge differently and each mode has different potentials/affordances in for expression that enables the production and the shaping of knowledge (Lim, 2011). The functional specialization of a mode over time means each mode has different potentials for representation and communication of scientific knowledge. This is important for learning as school curricular subjects draw on the semiotic resources of modes in different ways. Within the classroom, the work of the teacher often draws on semiotic resources of a range of modes (gesture, gaze, manipulation of models, speech, image, etc.). As such, researches on meaning making and student understanding through learning resources and mediation tools in classroom environment need a multimodal perspective.

The meaning potential of MDSTs is increased by deployment of various semiotic resources that have its own meaning potential or affordance to represent the intended meaning. This is succeed by the interaction and collaboration of various semiotic resources. Lemke (2000) posits that the interaction of different semiotic resources takes place in certain intersemiotic mechanisms and the resultant meaning is not mere addition of the meaning by the multiplication or extension of meaning. Hence, the main claim of multimodality is that modes have different meaning making potentials (affordances) for diverse communication purposes in a mediated action and if the modes, that are considered to provide best affordance for the communication purpose, are deployed and combined, the communication can be more meaningful.

2.1.2.2 Affordance

To make further clarification on multimodality, it is better to focus on the term "affordance" or "meaning making potential". The term affordance is key to multimodal approach. Gibson (1979) introduces this term in his study namely "ecological approach to perception". Gibson (1979, p. 127) describes the term of affordance as "the potential that is inherent in the environment regardless of its perception". What this means is "to perceive of affordance means to perceive some potential environmental resource and a means of action that will lead to an attainment of it".

Affordances in MDSTs are two-fold one of which is the increase in the inherent potential for one mode or semiotic resource system, and the other is the use of many modes to expand meaning and increase access to disciplinary knowledge. For meaning making of disciplinary scientific knowledge, Fredlund (2015, p. 59) coined the term "disciplinary affordance". In construction and communication of scientific knowledge, the inherent potential of the semiotic resources to provide access to disciplinary knowledge. The multimodal approach posits that if the semiotic resources that give best access to disciplinary discourse are employed meaning making of the content and construction of scientific knowledge is enhanced. Accordingly, monomodal text structure is assumed to low affordance or meaning making potential for the construction of scientific knowledge. Multimodal texts can help different learners to internalized or make meaning of the content by increasing the perceptual attainment.

Multimodality in this study deals with how the semantic patterns or elements (participants, processes, and circumstances in the content) at the level of discourse (in the stratums) realized as linguistic, visual and mathematical symbols patterns at levels of language, visual imagery, and mathematical symbolic modes. Parallel to O'Halloran (2005, 2007), three modes (written language, visual imagery, and mathematical symbolism) can collaborate together to form a MDST. The interplay and collaboration of modes generally has two functions, which are increasing the epistemic commitment (demonstration of scientific knowledge in disciplinary discourse in canonical ways of communication) and increasing the communication power (affordance) of the pedagogic science texts.

In short, features and characteristics of multimodal texts can be briefly expressed as in following. First, in the multimodal texts, the typological and topological meaning types can be brought together to contextualize meaning. As such, decontextualized meaning becomes contextualized. Second, multimodal texts can provide rich resources for both internalization and internalization of meaning. Accordingly, provide rich resources for creative externalized learning products. Third, multimodal texts can foster meaning making by bringing together the modes that have highest disciplinary affordance. Finally, by the construction of different intersemiotic mechanisms, the meaning making potential of texts can be increased.

2.1.3 Systemic Functional Theory

In this study, systemic functional theory (hereafter SFT) informs mainly three aspects for conceptualization, design, and evaluation of MDSTs. The first aspect deals with the metafunctional meanings represented by MDSTs. The second aspect involves the system choices in designing MDSTs. Last aspect engages with text grammar and realization of meaning in different grammatical stratums. In this way, SFT informs both MDST design and evaluation strategies. Michael Halliday developed SFT based on the view that language is “a social semiotic system, that is a resource for making meaning”. Halliday proposes that the functions that language has evolved to serve in society are reflected in its underlying organization. From this perspective, a major goal of SFT is to develop a functional grammar to account for the meaning making potential of language (Jewitt et al., 2016). This study involves the interpretation of social semiotic resources (resources of meaning) according to SFT of Halliday (2004). Regarding the semantic interpretation of meaning, SFT is a social semiotic theory where arising meaning depends on the context. SFT as an analytic approach that focuses on the text and it is interested in how meaning is constructed through the text. In this respect, SFT analyzes (1) how the systems of choices are (paradigmatic and syntagmatic), (2) how the choices made form those systems (lexico-grammar stratums), and (3) how the metafunctional meanings in the semiotic resources or texts are created (simultaneous metafunctional meanings). Accordingly, a MDST has paradigmatic and syntagmatic dimensions regarding system choices in design. It represents three simultaneous metafunctional meaning which are realized through grammatical stratums. The principles behind this proposition are explained as following.

The first principle is system choice principle (systemic). According to SFT, if a semiotic resource makes links with itself the situation of its use the discourse become possible (Fredlund, 2015). This posits the text context relation which “lies in the heart” of social semiotics. SFT envisages meaning making in terms of possible options of choices. The term systemic refers to the system choices, which are paradigmatic, and syntagmatic. The paradigmatic choices are made to represent the meaning units of the content and the syntagmatic choices deals with how to create a coherent text structure to demonstrate the whole content. For example, meaning potential of language is described in terms of set of contrasting options where each set is called as a system (or paradigm). Language as a whole is described by a “very large network of systems” (system network). In a MDST, these choices are determined or shaped by predetermined factors, which are mainly the science discourse which is a reservoir of system choices for making meaning and curriculum. What is more, teacher’s repertoire is another factor that affect the paradigmatic and syntagmatic choices for designing a pedagogical science text.

The second principle of SFT is metafunctional principle. Jewitt et al. (2016) remark that recent studies in multimodality recommend that the semiotic principles and properties which are conventionally attributed to language can also be found in other semiotic modes or modes. Functional side of SFT deals with how these choices function to produce meaning or how a semiotic resource plays different and various social function in producing meanings. These are conceptualized as metafunctions that are ideational, interpersonal, and textual. SFT conceptualizes the meaning making functions of semiotic resources in a social context in metafunctional view according to which semiotic resources simultaneously play three functional roles. Three metafunctions of semiotic resources in texts involve ideational metafunction which constructs particular state of affairs, interpersonal metafunction which “takes stance towards the state of affairs, and textual metafunction that organize meaningful parts into the whole. Metafunctional principle for multimodal texts proposes that different semiotic resources or modes simultaneously interact to create ideational meaning, interpersonal meaning, and textual meaning. Ideational meaning is further ramified into experiential and logical meaning (O'Halloran, 2008) (O'Halloran, 2008). The metafunctions are described as below.

a. Ideational metafunction deals with the construal of human experience. What is going in the text (processes), who or who is taking part (participating), when and where it is taking place (circumstance) construing experience is demonstrated by ideational metafunction. Further, ideational metafunction involves experiential metafunction and logical relations. The experiential meaning involves the processes, participants of these processes and the circumstances of the processes. Also, in deals with the types of experiential meaning among the participants of the text (e.g. mathematical relation, spatial relation). Logical relations deals with the logical connections or order between the action sequences taking part in the text.

b. Second metafunction is interpersonal which relates managing relationships within a text, reader, or writer. Interpersonal metafunction is the function of a semiotic resources in the present the roles and status that participants hold in any form of interaction, and here the interacting participants are the foci- this includes the participants who are interacting with each other, the viewer and the visual. The interpersonal metafunction regulates the power relations between the producer and reader of the text.

c. The third metafunction is textual metafunction. Textual metafunction or meaning is also called compositional meaning of the text. This metafunction manages the first two metafunctions and deals with the issues such as coherence/cohesion in a given text within display and material forms. The textual metafunction: the function of language through which a text can be recognized as having coherence and as making sense, rather than a series of unconnected words or phrases or sentences and the focal point here is the consideration of multimodal text in terms of its coherent structural elements of composition (O'Halloran, 2007; Royce, 1998). The main responsibilities of textual metafunction is referencing and relating the different parts of the texts. The relational devices in the text functions to relate different parts of the text such as mini-genres, items, components or even elements those will be mentioned in following parts. These relational tools or system choices are seen as arrows, lines and zone coloring. The underlying principle is the referencing endophoric and exophoric. Other principle is the logico-semantic relations where different parts of the texts are related to produce a logical sequence of actions.

O'Halloran (2008) proposes that the major strength of SFT for multimodal discourse analysis is the metafunctional principle that provides "an integrating platform" for theorizing how different semiotic resources and modes interact for creating and expanding meaning in a text. Metafunctional principle provides a basis for functionalities of semiotic resources and new ways for analysis the ways in which semiotic resources in MDSTs to fulfil a particular meaning making (semiosis) goals. Mapping the metafunctional organization of semantic flow across used semiotic resources in a MDST and cross-semantic mapping provides the opportunity of how semiotic resources are deployed to produce meaning and which meaning types are instantiated. The analysis of intersemiotic mechanisms (hereafter ISM) between different semiotic resources in a science text lies in this mapping (O'Halloran, 2008). Another strength of SFT is its concern on the instantiation of texts. Besides the metafunctions it looks are the "instances of the semiotic resource (e.g., language or a multimodal text) which is called as text where the choices are actually made from the system. Given with this perspective, SFT focuses on the structure of a MDST come into focus. This aspect deals with the syntagmatic organization of the text. The instances of choices or text is the perceivable material form of the content. The instances involve (1) syntagmatic choices, (2) the structure of the text, (3) order or sequence of different units of the text. Syntagmatic choices deal with the sequence of the semiotic resources within a text. It eventually involves the structure or composition of the text, which has a certain configurational order and composition.

The third principle proposed by SFT is the stratum principle, which engages the realization of meaning within instantiation of semiotic resources. The stratum approach in SFT models the experience as meaning, and when the metafunctional principle is applied, these experiences are modelled in each type of metafunctional meaning. The stratum principle looks how different paradigmatic choices used within syntagmatic configurations to realize meaning and each analyzes the metafunctions of the choices at each stratum. According to Halliday (2004), elements in each stratum are ordered in ranks. In the semantic stratum elements of the texts have rank. The lowest rank is word, and the highest rank is text. In order from more central elements to peripheral elements (1) Processes (what goes on), (2) participants (who or what is participating) (3) when and where, constitute experiential meaning. Lexico-grammar stratum the lowest rank is the word and the highest is the clause. To construe experience in language (or text) different elements of semantic stratum are in turn realized by different groups or phrases the lexico-grammar stratum.

As stated earlier, regarding the multimodal nature of discourse of science, written language, visual imagery, and mathematical symbolism modes can collaborate and complement each other to build a MDST which is synoptic or persistent. In the following part, the meaning making affordances and principles of these three modes are explained in SFT perspective. This perspective involves what kind of meaning (typological or topological) is represented by these modes, the system choices in these modes, and how the metafunctional meaning is realized in the grammatical stratums of these modes.

2.1.3.1 Language as a Semiotic Resource System and Linguistic form of Meaning Making (Semiosis)

According to O'Halloran (2008), language as a semiotic resource system is a syntactically as a chain (sequentially progressed) "where meaning culminates progressively as the text unfolds". Lemke (2000) expresses that language as semiotic resource system realized categorical types of distinctions. Language views typological view of reality (symbolic order of reality) where categorical distinctions are emergent in the transitivity systems where "participants process types, circumstances (kinds) are as particulate structures consisting of discrete categories" (O'Halloran, 2008). SFT views language in this regard and analyzes language as in sequence parts. These parts are cumulative, as the text unfolds, these combine, and produce meaning in a part-whole relation. The parts are words, word groups (phrases), clauses, clause complexes, paragraphs. Martin (1992, pp. 10–15) modelled the structure of language as in stratums of SFT in the Table 2.1. For linguistic semiotic resources, discourse and lexico-grammatical systems are organized around the constituent ranks scales depicted in the Table 2.1 below.

According to SFT, linguistic construction of ideational meaning is realized trough and within transitivity system elements where participants, processes, and circumstance are configured. These are the elements of a clause where the configuration creates and activity sequence in a particulate (element) level. O'Halloran (2008) notes that "larger activity sequences of processes and circumstances and processes" are delineated through ideation. This ideation instantiates the experiential meaning in the linguistic construction of meaning. Next, for the other part of ideational meaning that is logical meaning, linguistic logical relations are described and mapped through logical sequences taking place between clauses that are described in terms of "logico-semantic relations of interdependency" (O'Halloran, 2008). The discourse systems of conjunction and continuity in the language mode functions to describe the unfolding of logical relations in the text. The cohesive devices in language in content stratum are conceptualized in terms of "reference substitution and ellipsis conjunction", lexical cohesion (e.g. as, when, while..) (Martin, 1992, p. 286). The textual cohesive systems in the expression stratum (textual meaning) involves layout, position/location, font, color and alignment (O'Halloran, 2008).

2.1.3.2 Visual Imagery as a Semiotic Resource and Visual Forms of Meaning Making (Semiosis)

Kress and Van Leeuwen (2006) and O'Toole (1994) applied the systemic functional approach to images grammar of images. O'Toole also recruited Hallidayan "rank scale" to displayed art where the ranks are "work, episode, figure, and member" and so modelled how the meaning is instantiated through each stratum. While the construction of meaning proceeds from parts to whole in language, the construction of meaning in image proceeds from whole to parts. This fact is explained by gestalt of visual psychology by Arnheim (1969) who expresses that the whole is perceived before the parts. O'Halloran (2008) posits that for visual imagery, descriptive categories are required as analytical approaches that are different from the linguistic categorical type of system network of SFT. The content and expression strata of visual imagery is demonstrated as in Table 2.1 below.

For visual imagery, discourse and grammatical systems involve descriptive categories of visuals (icon, symbol, and index) and require analytical approaches, which do not require categorical-type system network adopted by systemic functional linguistics. Rather the analysis of experiential meaning in the whole image and related components involves examining the relations between scene, sub-scene, and components. For the logical meaning, the logical relations in visual imagery mode take forms of spatial, temporal, and causal relations, which unfolds in scene, sub-scene, and components. Logical relation typically made science genres as arrows, lines, or colored zones. Visual perception is topological in nature. Formulation of difference takes place in terms of degree where continuous variation included (O'Halloran, 2008).

Images in MDSTs make the realtions between symbolically encoded information visible or image can demonstrate the relations between different parts of the text. Arrows, lines or other figurative elements such as colored zones are the typical examples. This relating feature of image mode helps logical relations as a part of ideational meaning more visible and, so, immediately discernible to the reader/viewer (Royce, 1998) (Royce, 1998). In addition, the visual imagery mode can make the abstract or decontextualized information be contextualized. This is idea is proposed since image mode has an affordance the continuous changes in meaning the the topological setting of the content that is being mentioned in the text. Furthermore, (O'Halloran, 2007) posits that, this can be due to the higher modality in image mode which can "images produce an unraveled degree of certainty" that may not be found in other modes. This idea is similar with Royce (1998) who proposes that as the realistictness increases in images, the modality increases. The primary visual (whole image) going down the visual rank from the "who" figure portrays to the rank of member (body part of feature). In a multimodal text, each part is related to lexical items of language. For the ideational meaning, visuals show participants, participant features, the activities and processes, or circumstances, which generally creates setting or background. In an image or any part of an image, the visual message elements can be emerged as a person, a thing, or a process.

2.1.3.3 Mathematical Symbolism and Mathematical Forms of Meaning Making (Semiosis)

O'Halloran (2007) points out the close connection between mathematical symbolism and language. Accordingly, it is stated that mathematical symbolism is evolved from language. This close connection is quite observable from the ways in which how these two semiotic resources combine and collaborate in a clause level where elements from these semiotic resource systems can be used together to produce a coherent and meaningful text structure. O'Halloran (2007, p. 84) expresses that, for experiential meaning in mathematical mode, "the selection of relational and operational mathematical processes and circumstances" means that "the activity sequences unfold in a semantic domain largely concerned with relations between mathematic participants". In other words, the relations and operation within the unit of meaning involves quantitative experiential meaning relationship types among the interacting parties in that meaning unit. These relations between mathematical participants are instantiated in rank-shifted expressions as demonstrated in Table 2.1 below.

O'Halloran (2007) states that the strength of mathematical symbolism lies in an economy of expressions that are "unambigious" in meaning. It was stated as mathematical mode provides "a steady, calm, and abstract realm" where "a glance is sufficient to pick up relevant information" about the patterns of the quantitative relations that are verbally or visually demonstrated. This shows the synoptic view of reality (Tang, 2013). The semiotic resources in mathematical mode is considered in two perspectives. One perspective is the mathematical symbolism which involves symbols of participants, processes, or circumstances and formulations of these. Second perspective engages the integration of symbols and visual imagery features.

These are graphics or tables, which are used to demonstrate the quantitative aspects and meaning relations of elements.

Mathematical mode has higher meaning making potential than language in depicting quantitative relations between symbolized participants in the meaning unit (Liu & Owyong, 2011). Liu and Owyong (2011) state that symbolic formulas construe "a fused semantic product" between participant and process configuration and the categorical type of meaning goes in to topological by demonstrating the amount of the participants. This feature is realized semiotic metaphor within symbolization and semiotic transition. This means that the mathematical formula realized both typological meaning with demonstration of categorical symbols and topological meaning with presentation of the amounts (Liu & Owyong, 2011; Tang et al., 2011; Tang, 2013).

Table 2.1 The strata, ranks, and systems for language, visual imagery, and mathematical symbolism modes in SFT

Strata	**Ranks**			**Systems**
Content Stratum	**Language**	**Visual Imagery**	**Mathematical Symbolism**	Meta Functionally-Based Systems
	Discourse Semantics			
	Discourse Relations	Inter-visual Relations	Inter-statemental Relations	
	Lexico-grammar			
	Clause complex	Scene	Statement (clause complex)	
	Clause	Episode	Clause	
	Word Group	Figure	Expression	
	Word	Part	Element	

Table 2.1 The strata, ranks, and systems for language, visual imagery, and mathematical symbolism modes in SFT. (cont'd)

Expression Stratum	Typography Graphology Phonology	Graphics (color, framing, perspective)	Typography Graphology	Cross functionally-Based Systems

2.1.3.4 Text in the Perspective of SFT

Halliday (2004) describes text as an instance of language, which is structured "as a field of social action". Accordingly, in a multimodal perspective, a text is an instance of collaboration of various modes 'structured as a field of significant social action'. The syntagmatic and paradigmatic choices are the meaning potential of one sole semiotic resources system. In multimodal texts, since the number of semiotic resource systems or modes increases, the meaning potential of the text increases. This can be another reason of why multimodal texts have higher meaning potential than the monomodal texts. In language mode, for example, the meaning depends on the word chosen (building taxonomies) and how the chosen words are instantiated with the time or on the text. These syntagmatically choices mainly concern the textual metafunction in the text.

However, Fredlund (2015) posits that the choices in the semiotic resource systems are "not necessarily conscious". He posits that the choices made in the system are "the analytical choices made in the system". Choices made in the system may be resultant of, (1) a convention unthinkingly, (2) a habit that is acquired unreflectively, or (3) an unconscious impulse. This approach can inform a teacher in MDST design where the paradigmatic and syntagmatic choices from the discourse to demonstrate the content should be of the three instances above. Accordingly, text design engages teacher to design science text within a pedagogic aim where texts are considered to realize intended meaning. This study does not mean that teacher should design every text in their own ways, rather a meta-strategy is proposed to both analyze existing resources and choose the most appropriate ones, or design the texts according to the meta-strategy.

The relation between the paradigmatic (meaning potential) and the syntagmatic (instances) refers to the instantiation, which means that choices are made from the systemic network to produce a text (Halliday & Matthiessen, 1999, p. 14). Halliday and Matthiensen explicates how the text is instantiated with its meaning potential in a particular context with the concept of cline of instantiation. The cline of instantiation of a text is visualized in the Table 2.2 below.

Table 2.2 Cline of instantiation of meaning

Description	Potential	Subpotential/instance type	Instance
Context	Context of culture	Context of subculture	Context/Context of situation
Language	System	Register/Register Type	Text

If we think about the design of a 7th grade electric current text in science classroom, the categories emerge as in following. Table 2.3 below demonstrates the instances, contexts, and the semiotic resources systems on how the paradigmatic choices and syntagmatic choices for presenting scientific knowledge.

Table 2.3 Cline of instantiation of meaning in an exemplary science text

Description	Physics as a discipline	Electricity	Electric current
Context	Pedagogy/Didactics	Science Course	7th grade science lesson for electric current.
Semiotic Resource System	Language, visual imagery, and math symbolism	MDST with minigenres, items, and component.	MDST of electric current.

The ideas proposed by the social semiotic theory, systemic functional theory, and Peirce's proposal on meaning making (semiosis), the concept of mediated action can be demonstrated through the model developed by Bateman (2021) in Figure 2.4 below. This model effectively demonstrates the relations and the interactions of the mentioned concepts. The yellow circle demonstrates the concept of 'sing' (or MDST) which are constructed in a certain material through a certain grammar. These materiality and grammar take place in certain discourse semantics (discourses of science and science classroom) phylogenetically developed by a certain community. The material side of the yellow circle mostly engages the material aspects of modes (proposed by multimodality), and the other part is mostly related with the grammatical aspects proposed by SFT. The green part of the model explicates how the intended meaning is realized and valued as meaningful in a certain social context. This is related the ontological status of the material and the meaning

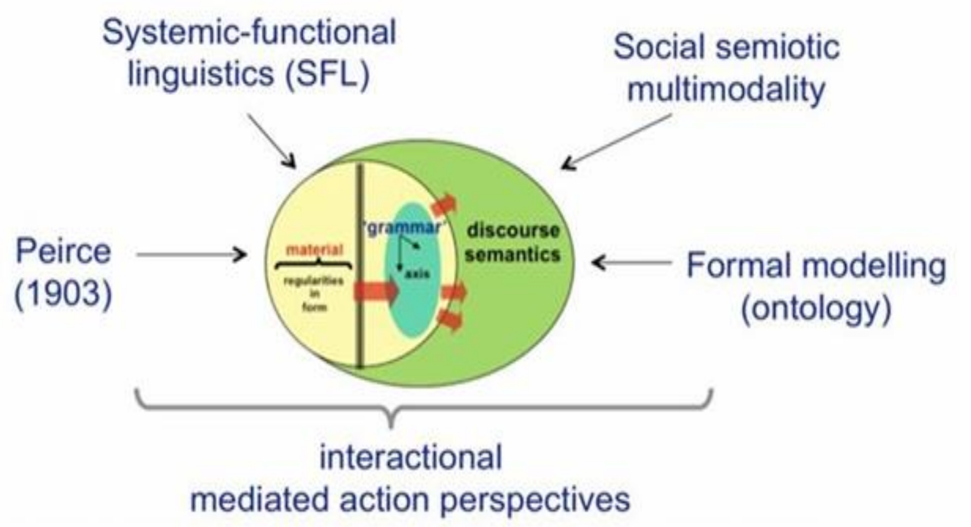

Figure 2.5 Modelling of the ınteractional mediated action.

2.1.4 Discourse of Science and Didactic Science Texts

O'Halloran (2005, p. 10) states that science seen as 'multisemiotic' construction since the discourse of science is constructed through "choices from the functional sign systems of language, mathematical symbolism, and visual display. Christie (1998) remarks that scientific knowledge is uncommon sense which is "esoteric" and "its expression requires some new uses of language". At the beginning it is quite inaccessible for making meaning or making sense and its mastery generally require ontogenetic timeframe in which an individual gradually develops the mastery on discourse and practices of science. Therefore, understanding the discourse of science is vital to construe experiences in classroom activities or daily life experiences as a scientific knowledge (Airey & Linder, 2009; Liu & Owyong, 2011). Learning or understanding discourse of science, therefore, has a substantial role in science teaching and learning. Discourse of science mainly involves the communicational landscapes of scientific knowledge and practice of science. The specific sign systems and grammars enable scientists to communicate scientific knowledge by providing access to the inherent meanings. This sign systems and grammars are evolved in phylogenetic time frame where communication of scientific knowledge is characterized as multimodal (Jewitt et al., 2001). Since discourse of science is multimodal involving disciplinary semiotic signs, teachers need to understand the multimodal nature of discourse of science to select, design, and provide students with effective science texts for making meaning of scientific knowledge as accessible as possible or as meaningful as possible.

O'Halloran (2007) O'Halloran (2007) posits that texts are the products of multimodal semiotic system choices which characterizes the text as both generic (standardized patterns) and specific to the context. The science textbook is considered as a generic mix where miningenres includes laws, theorems, narrations, explanations, problems, solutions etc. Scientific Genres are defined as reports, explanations, experiments, biography, exposition, and narrative (imagination) by Halliday and Martin (1993, p. 205). From the system choices to internalization of meaning, the instantiation of meaning through science texts follow this path. The system (generalized meaning potential), genre/register (semantic, subpotential), text type (generalized instance), text (actual instance), and reading/viewing (subjectified meaning or lived object of learning). Being informed by Tang et al. (2011), we can visualize the multimodal instantiation with specific example in the Table 2.4 below.

Table 2.4 Multimodal instantiation order of scientific knowledge in didactic science texts

<table>
<tr><td rowspan="6">Multimodal Instantiation</td><td>System</td><td>Physics Text</td><td rowspan="6">Multimodal Text</td></tr>
<tr><td>Genre</td><td>Pedagogic Physics</td></tr>
<tr><td>Register</td><td>The content</td></tr>
<tr><td>TP</td><td>DRA/Hierarchy, relationship</td></tr>
<tr><td>Instance</td><td>Enacted Object of Learning</td></tr>
<tr><td>Interpretation</td><td>Lived Object of Learning</td></tr>
</table>

2.1.5 Variation Theory of Learning (VTL)

Kulgemeyer (2018) proposes that the texts used in instruction and teaching can be considered a as kinds of instructional explanations which are "often conducted practice in all kinds of teaching" and "important teaching technique in science". Based on the idea of Gage (1968), who posits that explanations intend to "engender comprehension", Kulgemeyer (2018) reports that explanations are employed in all kinds of teaching practices, therefore, they are vital for all teaching and learning activities. Variation theory of learning (hereafter VTL) informs pedagogical aspects/dimensions for MDSTs. It guides the didactic aspects of MDSTs. Didactic texts should have such a structure that have intristicly and naturally its affordance or high meaning making potential (Gibson, 1979). According to Gibson (1979) "one learns to see the world in new ways by coming to 'discriminate' or 'differentiate' one's perception of the world" where initially undifferentiated and vague entities or concepts become more differentiated within perceptual learning. In other words, more differences are "discerned" in the object of learning (content) represented by a MDST. Discernment, thus, critically important for learning from didactic texts. To discern something is being able to differentiate amongst the various aspects (facets) of some given phenomenon and hence be able to focus on most relevant aspects.

VTL asserts that "without variation there can be no discernment and without discernment there can be no learning" (Marton & Tsui, 2004, p. 64). As such, the didactic texts need to be designed in terms of variation to make the critical aspects discernible. VTL characterizes learning in terms of differentiation and perception. Learning from a MDST proceeds from an ambiguous undifferentiated whole to a differentiated and integrated structure of ordered parts. The main argument of VTL is the differentiated learning deals with discernment, which is possible with variation. VTL posits that three "interrelated and inseparable" conditions that must be met in order for learning take place. The first is variation. Variation is necessary condition for making an aspect noticeable. Booth and Hultén (2003, p. 70)defines variation as "some particularly critical feature of the material that they are learning can be brought out of a taken-for-granted back ground by meeting around that feature". In other words, it refers to foregrounding and backgrounding features of the learning content regarding their criticalness and taking-for-granted some aspects. Critical feature is described as the special pedagogical value on that dimension of variation and critical aspects are the dimension of variation. Therefore, the variation around a critical feature of the content “opens up a critical aspect” (Fredlund, 2015). Two kinds of variation exist. The first is implicit variation that involves presenting a single instance of object of learning “that could be varied but not varied”. Here the text provides only one instance, and no contrasting options are presented. The second type of variation is explicit variation which variation involves more than one instance of critical aspect. MDSTs provide multiple instances, examples or contrasting options. Explicit variation involves more than one instance of critical aspect. Variation relates the content and the structure of the text and regulates the pedagogical aims with the structure.

Second condition is discernment, which involves experience of a particular feature of the text. Fredlund (2015) posits that, “variation must be experienced so that critical aspects can be discerned”. One critical point in discernment is the discernment of something within its context, not isolated. Therefore, an object of learning needs to be discerned in its context and other backgrounding aspects. The third condition of learning according to variation theory of learning is simultaneity. Simultaneity condition requires simultaneous presence of critical aspects’ contrasting options and experience of the options as a whole (Marton & Tsui, 2004, pp. 16–17).

Since the object of learning is demonstrated through the text, which is didactic, it is designed within certain learning goals. To fulfil the aims, one way is design the text in way that can help reader or viewer to discern the critical points and themes in the text. Therefore, text designers purport to design a text structure and content to fulfil this aim. While VTL as a pedagogic strategy that help teacher to determine that what aspects the learner should discern most and what discern less, multimodality, in this study, provides text analysis, design and evaluation strategies that may help teachers to create pedagogical texts suggested by VTL.

The information in a didactic text is constructed in a hierarchy where pieces of information is described as critical, peripheral and margin (Marton & Tsui, 2004).

The focus of the text is the critical aspect, the theme or surrounding information is the peripheral aspect. The most irrelevant information in the text is described as margin. A text is expected to demonstrate the information regarding this hierarchy and help learner to focus on this respect. Most critical aspects should be mostly differentiated and discernible. The way to achieve is to create variation around those aspects. In the learner perspective, it is related to being focused on the important and critical aspects of learning subject. A text should designed in a way that help learners to focus on those critical aspects and related parts. In the text structure, the most critical aspects are in the focal awareness, the peripheral aspects "surround theme" and the irrelevant aspects construct the "margin" (Marton & Tsui, 2004, p. 190). To utilize the variation strategy for enhancing learning, a systematic way in which "variation is created to make possible the experience of different aspects and how they are related to each other" is recommended and called as patterns of variation (Fredlund, 2015, p. 65). This strategy can be used as a pedagogical strategy when making meaning through MDSTs in gifted science classroom.

A didactic text aims to represent an object of learning which is described as a "well defined area within the field of subject matter that makes up the content" (Fredlund, 2015, p. 66). It provides "a more detailed picture of what needs to be learned to meet learning goal" therefore, it is different from a learning goal (Fredlund, 2015, p. 66). Object of learning is novel to students; teachers need to think about the necessary conditions for learning which can be described regarding patterns of variation and invariance. Marton and Pang (2013) claim the point of departure for a powerful and effective teaching should be the question "what and which students need to learn?" In this respect, Fredlund (2015) summarized the role of teacher regarding this proposition. The teacher firstly needs to find out and demonstrate what the educationally critical aspects of the object of learning are. Secondly, she needs to determine the "appropriate dimensions of variation" which is not simple process. Patron et al. (2017) argue that this can be done with a social semiotic reasoning of the content and material design. This can be done by use of thematic pattern strategy (hereafter TP) and revealing of disciplinary relevant aspects. Third, as

Booth and Hultén (2003) proposed, after the determination of aspects and critical aspects of the content, teachers should create variation around the critical aspects.

2.1.5.1 VTL and Thematic Patterns

Royce (1998, p. 26) describes SFT as an "exotropic theoretical paradigm which inherently allows (through its usage) the ability to explain a range of communicative phenomena and work with other paradigms". As such, SFT can be employed to explain the meaning making processes in MDSTs in collaboration with VTL. For the analysis of science text, Lemke (1990) takes SFT as a point of departure and develops the idea of thematic formation and TPs. Lemke (1990, p. 202) posits that, although a person can think, talk, or write about the particular knowledge structure or concept, her or his actions must be performed through semiotic resources and in way these conforms to "repeatable social patterns to be recognized in the social context of certain community". These recognizable or meaningful patterns are called as thematic formations which are sorts of institutionalized ways of communication. According to Lemke (2000) and Lemke (1990) a scientific concept is "a network of meaning relationship" which is demonstrated through the use of multiple modes of representation and semiotic resources. Tang et al. (2011, p. 1779) consider that "what makes a scientific concept correct or meaningful is the canonical and recognizable ways of assembling these relationships according to the discourse practices of a scientific community". Therefore, the semiotic construction of scientific knowledge is the deployment and enactment of meaningful texts and actions, which mediate learning by use of "assembling the network of meanings across various representations. This mediation is made through use of various modes and semiotic resources that are canonical and recognizable in science community and classroom. Students need to transform experience into meaning by appropriately engaging with specific semiotic resources to become disciplinary resources to become disciplinary literate or disciplinary fluent. Therefore, the texts is expected to be designed within the disciplinary discourse (Airey & Linder, 2009).

In this respect, Lemke (1990) developed TP approach where the transitivity system inherent in ideational meaning (content) is analyzed and mapped at particulate level (element level) in semantic stratum of language or the semiotic resource systems. TPs provides more detailed analysis of didactic texts. The thematic pattern strategy is further applied to multimodal texts by Tang et al. (2011) and Tang (2013). Thematic pattern strategy is used to determine the semantic stratum elements and the experiential meaning relationship between them. This helps us to see what meaning types of participants, processes, circumstances, and experiential meaning relationships are demonstrated in semantic stratums in components within the text.

The particulate elements of semantic stratum are further categorized and the relationship between the participants of the content. Participants are categorized into actors and goals. Processes are categorized into material, mental, verbal relational, and existential. Finally, circumstances are categorized as location (time and space) and extend. Tang (2013) made a synoptic text analysis that have been realized in multimodal science texts and concepts are demonstrated through particulate elements and those are shown in modes. This means that TP strategy can be well applied to multimodal texts to see which sematic elements are demonstrated by which semiotic resources or combination of semiotic resources. As such, TPS can be used as an effective tool to both design and analyze meaning making in MDSTs.

Lemke (1990, pp. 87–91) suggests that teachers should attempt to create TPs for the content that they teach. In this respect, (Fredlund, 2015) well explained and explored the relevancy and collaboration between SFT as analytical framework for meaning making and VTL as pedagogical strategy to both analyze and design MDSTs.

2.1.5.2 Patterns of Disciplinary Relevant Aspects

Lemke (1990) posits that “science texts are characterized by certain regularities, certain recurring thematic patterns, also called thematic formulations or thematic systems”. In a science text, within these regularities disciplinary relevant aspects (hereafter DRAs) are demonstrated. Science texts are generally made of highly conventionalized systems of meaning relationships among terms and concepts. Characteristic features of science texts are also expressed by Halliday and Martin (1993, p. 243). DRAs are canonical and recognizable ways of assembling the relationships according to discourse practices of scientists' community (Tang et al., 2011). These DRAs construct the science content or subject matter. In order for teaching the content, it is a requirement to determine the DRAs and after determining the pedagogical and material strategy to demonstrate the content of scientific knowledge in a didactic text. Thematic pattern strategy is a powerful strategy for analyzing and map the DRAs (Fredlund, 2015; Tang et al., 2011). By this way the DRAs are analyzed in the semantic stratum of SFT approach and the particulate elements within paradigmatic and syntagmatic choices are mapped and the meaning relationship is revealed.

2.1.5.3 Variation Theory of Learning and Disciplinary Relevant Aspects

Fredlund's (2015) synoptic text analysis aims to foreground the DRAs in the text extract, which is realized explicitly or implicitly through different semiotic resources. Fredlund well demonstrated the particular interconnections that can be made between DRAS and VTL's critical aspects and criticalness hierarchy. This means that a pedagogical approach and a text analysis approach is integrated, and the pedagogical implications are investigated. Fredlund claims that in order for constituting scientific knowledge and resultant meaning students need to experience contrasts and focus on parts and whole and relations between them. He also well demonstrates the connection between the "reconstruction of awareness" and the evolution of semiotic resources. Furthermore, the experience within the material system of the text is foregrounded as a vital component of meaning making. Therefore, the text must be designed in a way in which student meaning making (semiosis) of content will be at highest stake.

DRAs are figured out through the thematic pattern strategy which is based on SFT. The connection between VTL and the DRAs as analytical units is that "the analytical unit DRAs essentially has some characteristics as the unit "critical aspects that VTL uses to characterize patterns of variation that are needed to be enabled classroom learning". Therefore, Fredlund (2015, p. 123) posits that the identification and enactment of the critical aspects of the object of learning is vital for to make classroom learning possible. The compatibility and usability of TPs strategy with the determination of patterns of variation for enhancing meaning making of science content show that approaches derived from social semiotics and SFT may effectively inform the meaning making processes in science classroom.

The object of learning is in the focus for the both perspective and for enactment of the object of learning, it is necessary to provide the pattern of variation which allows DRAs to be discerned (Fredlund, 2015). The DRAs of a content can be realized through the paradigmatic system choices (semiotic resources and modes) and syntagmatic system choices in a MDST. Explicit variation deals with the variation for many contrasting options or instance, and implicit variation is the different contrasting situation in one option or instance. To make the critical aspects in DRAs the explicit and implicit realization is favored to increase the discernibility and, so, understandability of these aspects. To make implicit recognition of the DRAs and the underlying critical aspects the explicit variation mentioned above is necessary.

Table 2.5 Relationship between DRAs and VTL's critical aspects

DRA	VTL's critical aspects.
The educationally important partsof OL seen from the discipline perspective.	The educationally important parts of an OL seen from the student's perspective
This is determined by the disciplinary knowledge and thecurriculum.	These are determined by the teacher within the pedagogical aims, which consider situations about student learning such as prerequisite knowledge or abstractness of the content. Here teacher is expected to make social semiotic reasoning that is explained by (Patron et al., 2017).

Fredlund (2015) posits that, "contrasts may be noticed by topological or typological characters" as in demonstrated in the Table 2.12 (e.g difference between air and water is typological or topological). In short, variation by kind and degree helps implicit variation and explicit variation helps different contrasting options of same entity. The designers of science texts are expected to make choices from the systems that are inherent in each metafunctional meaning and these choices must provide best access to intended meaning. The chosen semiotic resources and text compositions should give access to DRAs, which determine the aspects and the criticalness hierarchy. The initial aim of a teacher in designing MDST should be to help students to discern the DRAs of object of learning, and this can be done "by opening up the variation around theses critical aspects. Explicit and implicit variation need to be created.

DRAs are mediated with the signs systems and conventions of the discourse community. Therefore, it is better to use the modes and semiotic resources those have disciplinary affordance (Tang et al., 2011). The patterns of DRAs can be realized through the design and use of semiotic resources. According to Fredlund (2015, p. 125), the question here is to choose which semiotic resources that are most appropriate to provide best access to intended meaning. While this depends on the repertoire and the "level of appreciation of the disciplinary affordance of different semiotic resources, it is recommended that the initial aim is not the selection of semiotic resources. Rather, the 'which details' or aspects need to "be communicated "to them, in other words, "putting the object of learning in focus". This means that the DRAs and details comes first, the selection and arrangement of semiotic resources within modes is next to demonstrate intended meaning. Parallel to Fredlund, this study does not recommend or give priority to any semiotic resource of mode for demonstrating scientific knowledge. However, the priority in text design is given to determining the meaning (three metafuctional meanings) that will be demonstrated and selection the appropriate system choices and modes that have best meaning potential for providing access to intended meaning.

2.1.6 Multimodal Didactic Text Design Strategies for Science Teachers of Gifted Students

Norris (2011) describes multimodal actions as higher-level action, lower level action, and frozen actions. The designing of MDSTs can be considered as a multimodal action, which have aims, intentions, choices, and materializing processes. The choices in this multimodal higher level action is pragmatic (Goodwin, 2000), and these pragmatic choices are motivated by the pedagogic strategies/intentions of ISToGs to realize intended meaning. The text itself can be considered as a frozen action that is the product of higher-level action. Therefore, being informed about the intentions in the design and analyze the text itself according to SF-MDA and VTL, we can demonstrate how the pedagogical aims are realized through the instantiation of the text.

The thematic pattern strategy is mainly used to figure out and map the DRAs in a science content. Thematic patterns are patterns of DRAs show the relationships between different thematic items that are analytically distilled out of the content. Therefore, this strategy is the first as an analytical tool to use in designing or evaluating a science text. This analysis is done at firstly component level to map the transitivity system elements at the semantic stratum (processes, participants, and circumstances) and figuring out the meaning relationships between them. After the mapping of the transitivity system element, the criticalness hierarchy can be made for the content built up by these elements. Here the strategies drawn form VTL and SFT co-operate together to construct a meaningful didactic science text.

The elements of this higherlevel action can be considered in following part as multimodal text design strategy.

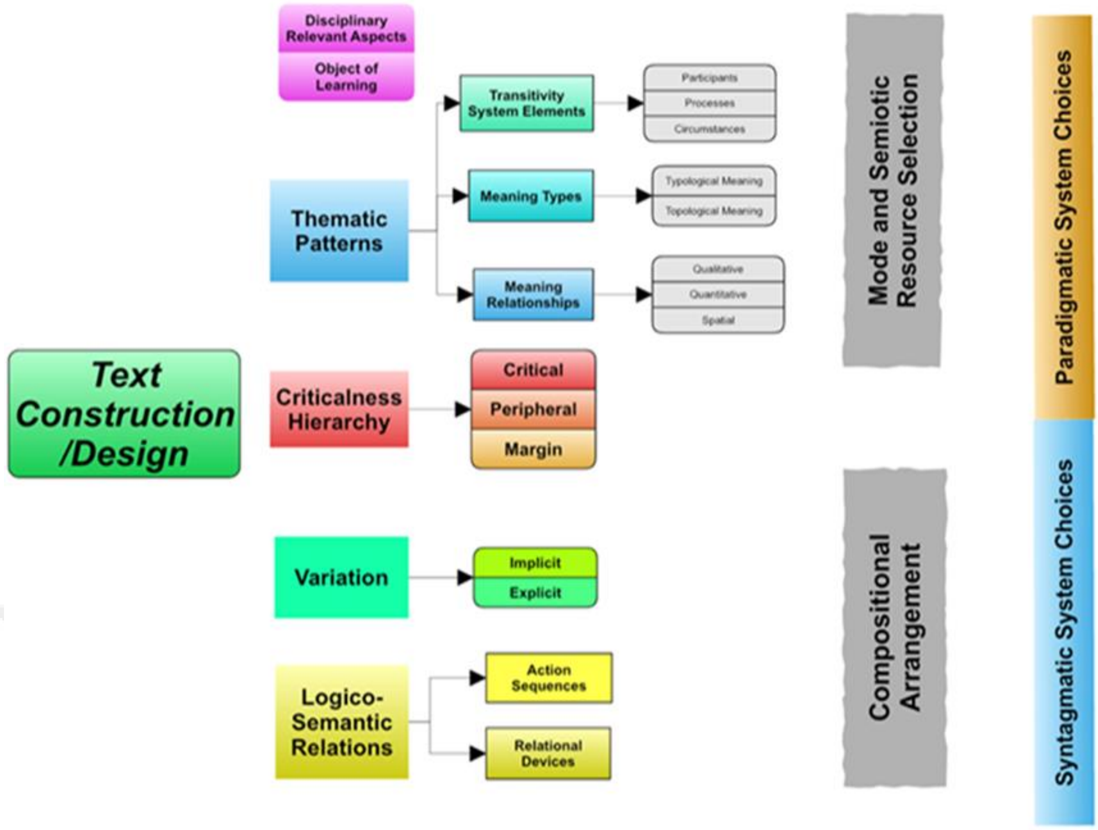

Figure 2.6 An overview of MDST design strategies

MDST Design Strategy

a. Determination of disciplinary relevant aspects. In the direction of learning goals, determination of critical aspects, peripheral aspects and margin in a science content.

b. Mapping of thematic patterns of each disciplinary relevant aspects within each scale is done. This step involves the analysis of transitivity system elements of the content. By this way participants, processes, and circumstances and experiential meaning types are determined.

c. Choosing the most appropriate semiotic resources (and modes) to represent intended meaning. These resources are expected to contextualize meaning and hence they need to provide best affordance and disciplinary affordance. The multimodal ensembles are designed with various intersemiotic mechanisms above to realized intended meaning and demonstrate various facets of the critical aspects. The design operations include, lexicalization, symbolization, visualization, symbolization (re-semiotization).

d. Making the text composition regarding criticalness hierarchy of aspects. This requires making different facets of the critical aspects more discernible in a comparison to the other aspects lying in the text. This is done by layout and materiality text design elements. Juxtaposition, font size, font color, spatial relations, and orientation of text elements.

e. Explicit variation for the critical aspects of the content is expected in the text.

f. What is more logical activity sequences and relations between scales of the text are done by use of relational tools mentioned above.

g. Creating relational devices for the different meaning units of the text for demonstrating the logico-semantic relations and action sequences.

The first three aspects deal with the paradigmatic dimensions of MDSTs. Remaining design strategies deals with syntagmatic dimension of MDSTs. In this respect, this MDST design framework provides comprehensive strategies, which binds the form and function with pedagogical intentions of an ISToG.

The success criteria in demonstration of ideational, interpersonal, textual metafunctions and according to mixed mode semiosis approach are expressed in following. The representations of semantic stratum elements are expected to involve discrete and continuous variations. In other words, topological and typological meaning types of participants, processes, and circumstances expected to demonstrate for a successful contextualizing of meaning. As argued before, the contextualizing of meaning leads to expand and multiplying of meaning which are the main characteristics of a multimodal text that enhance meaning making of the content For example, to use a semiotic resource in a mode that demonstrates topological and typological meaning for a process, visual imagery mode is expected to use with language or mathematical symbolism.

What is more, VTL also suggests that if the explicit variation exists for critical aspects, the critical texts can be more understandable. This requires providing of different contrasting options or instances of critical aspects. For example, if a teacher aims to demonstrate type of a wire as determining factor for resistance, it should be better if another type of wire is presented and the resistance of two is compared. The success criteria for interpersonal meaning in a multimodal pedagogic text are presented in following. First determination of critical aspects, peripheral aspects, and margin aspects is done. Second this hierarchy is demonstrated within text structure by dividing text into separate scalar units/parts and making these parts more or less discernible depending on their place in the criticalness hierarchy in a way that the learner will be able to understand that this is the critical aspect and highest perceptual discernibility can be succeeded.

The success criteria for textual meaning involves how the different scalar parts of the text is foregrounded and backgrounded, how the are located, how they are sized, and how they are separated. These strategies are the compositional features of the text, and variation in these features are expected regarding the criticalness of the represented content and relations between them. This enhancement involves contextualizing of meaning through this combination of semiotic resources. The contextualizing relations are co-contextualizing and re-contextualizing relations that are created within various intersemiotic mechanisms.

Figure 2.7 demonstrates features of an effective didactic science texts regarding paradigmatic and syntagmatic choices. Accordingly, an effective didactic science text is considered as multimodal, providing best affordance, contextualizing meaning, having rich semiotic resource, and expanding meaning. In this respect, the paradigmatic and syntagmatic choices can meet such features. In the paradigmatic dimensions expected specifications are high mode level, existence of typological and typological meaning types, rich and various intersemiotic mechanisms, and explicit variation around critical aspects. Regarding the syntagmatic dimensions, the texts is expected to be centered oriented, foregrounded, and backgrounded, having degree of framing elements, having relative sizing.

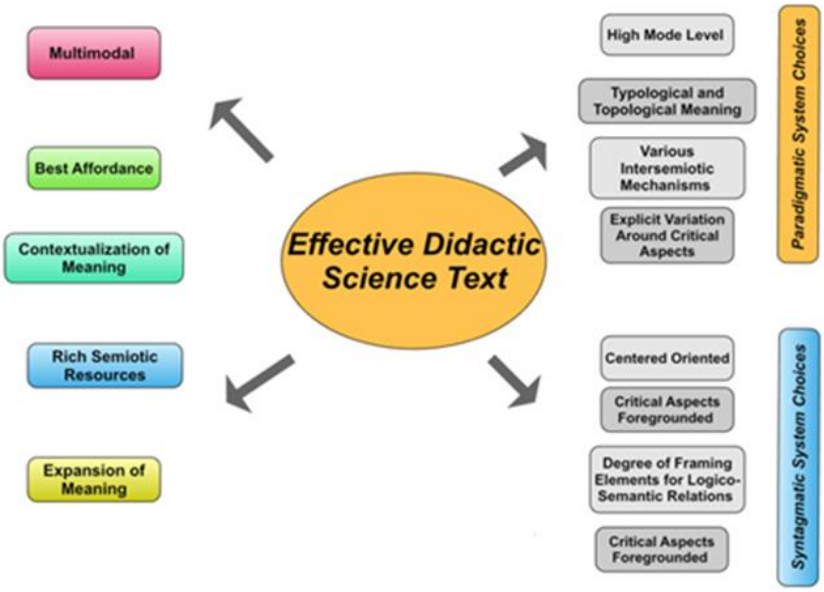

Figure 2.7 Characteristics of an effective didactic science text

2.2 Theoretical Framework for Analysis and Evaluation of MDSTs

This part the theoretical backdrop for analysis and evaluation of MDSTs. The framework developed for the analysis and evaluation of MDSTs is not independent from the theoretical considerations mentioned for conceptualization of MDST. The analysis and evaluation strategy involves analysis of the intersemiotic mechanisms and metafunctional meanings emerged from intersemiotic mechanisms between different modes. Next scalar hierarchy principle, which helps dividing a MDST into smaller meaning units. This helps to observe the paradigmatic and syntagmatic system choices and intersemiotic mechanisms realized/instantiated in different text scales and stratums.

2.2.1 Systemic Functional- Multimodal Discourse Analysis

Social semiotics posits that, language as a semiotic resources system has it own regularities and conventional ways of uses such as texts, registers, and genres. As such, this idea is extended to other semiotic resources systems (e.g. visual imagery, mathematical symbolism). These modes differ regarding stratification, rank, metafunctions (O'Halloran, 2007). For the synoptic (persistent) texts (pager or screen based), Systemic Functional- Multimodal Discourse Analysis (hereafter SF-MDA) views science discourse as constructed through the deployment of three modes which are language mode, visual imagery mode, and mathematical symbolism mode. In this study, the SF-MDA approach (O'Halloran, 2005, 2007, 2008) is used as a meta-approach for "conceptualizing the meaning arising from the integrated/complemented use of these three modes on MDSTs.

SF-MDA can be applied to any field of activity that involves human communication (Jewitt et al., 2016, p. 55). Similarly, systemic functional approaches to multimodal discourse analysis (SF-MDA) are concerned with the 'grammatics' of semiotic resources, with the aim of understanding the functions of different semiotic resources and the meanings that arise when semiotic choices combine in multimodal texts (O'Halloran & Lim, 2014). SF-MDA involves so-called multimodal grammatics, where interacting systems of meaning are a key motifs. In this regard, the processes of intersemiosis, where semiotic choices interact and combine, and re-semiotisation (Iedema, 2001), where semiotic choices are re-construed within and across multimodal texts, is central to the approach.

SF-MDA involves metafunctional principles that deal with the form/meaning problem and simultaneously provide a platform or backdrop for the meaning emerging from the integration/collaboration of semantic choices through the idea of that is semiotic resources contextualize each other to produce new meanings (Liu & Owyong, 2011; O'Halloran, 2005). SFMDA provides the systemic functional semantic, lexico-grammatical and, expressional stratum and rank-shifted systems for the semiotic resource systems (modes) other than language.

For this study, SF-MDA mainly concerns with two main issues. The first is to develop frameworks to investigate the functionality and grammatical systems for the modes which lies in MDSTs (here language, visual imagery, and mathematical symbolism). Second is the theorization of meanings arising from the integrated or combined use of these modes used in the texts. These two issues are previously investigated by (O'Halloran, 2005, 2007) for mathematics discourse. To tackle with these concerns, O'Halloran (2005) well conceptualized the ISMs between these three modes, which shed a light on the meaning aroused from the combined use of different modes and helps to theorize a phenomenon that has a fluxional and multi-facetted character. Secondly, O'Halloran (2005) explores the semantics of the intersemiotic relations in terms of contextualizing relation to see how the meaning is extended or multiplied by the use of these different modes.

2.2.1.1 Intersemiosis, Intersemiotic Mechanisms, and Semantic Multiplication in MDSTs.

O'Halloran (2007) claims that understanding the intersemiosis phenomenon is central to SF-MDA approach for multimodality. In this respect, investigating the ISMs between modes provide powerful insights on produces meaning in a MSDST. ISMs organize two or more modes into a "coherent multimodal message" (Liu & Owyong, 2011). The analysis of ISMs adds our knowledge of the nature of multimodality. Different semiotic resources work together in various contexts to project a unified coherent message to their readers/viewers (Royce, 1998). Intersemiosis refers to co-operation of different semiotic resources and modes to produce "a single textual phenomenon" (Royce, 1998). The potentials of elements in the act of combining to provide a total effect that intersemiosis is greater than the sum of the individual elements or contributors and this is how the synergitism of different modes in texts is achieved/realized. Royce explored how language and image mode co-operate together to produces a unified coherent message in page-based multimodal texts. The ISMs reveal how the cohesion between different modes to instantiate certain meanings. These metafunctionally-based strategies are obtained from Halliday (2004) who paves a basis for intersemiotic mechanisms by explicating the categories of lexical cohesion for ideational meaning. Cohesion is one of the fundamental features of the text. It refers to the "relations of meaning that exists without the text, which define it as a text". It is an underlying factor to help to demonstrate the meaning of a single text element in relation to other elements and the whole meaning derived from the interplay of all semiotic elements in the text (O'Halloran, 2008).

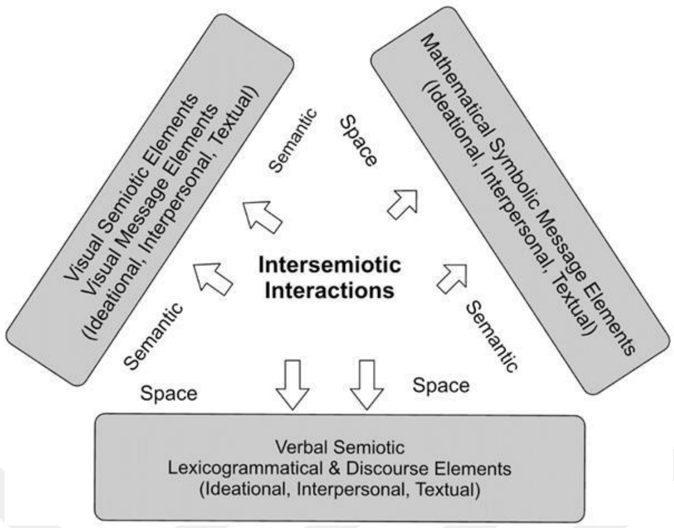

Figure 2.8 Intersemiotic interactions of language, visual ımagery andmathematical symbolism in MDSTs

Intersemiotic interactions taking place in MDSTs create the meaning inherent in the text. Hence, the only way to understand how meaning is realized depends on the understanding of the mechanisms in which the intersemiotic interactions take place (see Figure 2.8). The intersemiotic interactions between different modes result in expansion of meaning in the semantic level. The expansion of meaning arises through the contextualization of meaning (Lemke, 2000). The point of departure for contextualization of meaning in this study is the existence of discrete and continuous variation in the representation of meaning for the ideational meaning. In other words, if the typological and typological meaning is represented the contextualizing of meaning take place. For the textual meaning if the selected semiotic resources are arranged and demonstrated regarding criticalness of disciplinary relevant aspects in the text composition, this represent the another dimension of contextualization in the text.

Tang (2013) remarks that the increase in the modality level leads to contextualization of meaning since different modes have different potential to demonstrate continuous and discrete variation in meaning. Intersemiosis creates new semantic layers, which stem from contextualizing relations. Co-contextualizing and re-contextualizing relations, re-construe reality, which is beyond of affordance in an isolated mode. Re-contextualizing relations can be metafunctionally-based because the relations discussed above largely involve processes, participants, and circumstances (and experiential meaning) in MDSTs. These experiential relations permit the re-contextualization or expansion of logical meaning. What is more, these ISMs involves the compositional (syntagmatic) features of the text. This means that text composition provides a powerful ISM, which afford to alter meaning made from the text. The intersemiotic mechanism regarding text composition or textual meaning co-contextualizes the meaning posed by the text. For example, making a change in the order of text elements such as mini-genres may affect the logical relations among these elements or changing dimension of an element may mean that this element is more important than other parallel to (White, 1982)White (1982) who posits that size is an indicator of importance.

2.2.1.2 Mixed Mode Semiosis

Intersemiosis plays a crucial role in constructing scientific knowledge for “meanings made in each functional resource in each semiotic modality can modulate of each kind in each other modality, thus applying the set of possible meanings that can be made (Lemke, 1998). According to Lemke (2000), this modulation is achieved, for example, through different two modes one of which involves continuous variation and another involves discrete variation. As such, meaning is multiplied. To analyze how the modulation is progressed, the underlying intersemiotic mechanism is examined.

Why semantic expansion occur intersemiotically? Lemke (2000) provides an approach that proposes different modes instantiate topological and typological meaning types In the mixed-mode semiosis approach of (Lemke, 2000) the contextualizing relations are defined in terms of the interaction of different meaning types conveyed by different semiotic resources. The idea is that if a semiotic resource that represents discrete variation in meaning (typological meaning) and another semiotic resource that represents continuous variation in meaning (topological meaning) interact, there happens a contextualizing relation between them and, the resultant meaning is an expanded form of the previous two. Since contextualization "opens up interpretative space in which semantic effervescence can be accessed" the multiplication of meaning take place (Lemke, 2000). Semantic expansion take place through mixed-mode semiosis because mapping across topological and typological forms result in the system giving rise to a new space of interpretation of meaning.

2.2.1.3 Intersemiotic Mechanisms

ISMs in content and expression strata are developed to capture and analyze how meaning is expanded through the interaction, combination, or collaboration in of different semiotic resources and modes in a MDST. Since the intersemiotic interactions lead to contextualizing of meaning, intersemiotic mechanisms are firstly categorized into two main relationships of contextualizing. Co-contextualizing relations of parallelism where convergence of meaning take place. Re-contextualizing relations of dissonance where divergence of of meaning take place.

Royce (1998) developed a framework, which constructs a basis for the formulation and mapping of ISMs between the language and image mode in MDSTs. O'Halloran (2005, pp. 163–171) re-formulated the ISMs between language, visual imagery and mathematical mode in a multimodal text and posits that the co-contextulizating and re- contextualizing relations take place across these semiotic resources and modes in the following ISMs. The ISMs across Language, visual imagery, and mathematical symbolism. (O'Halloran, 2007, 2008) O'Halloran (2007, 2008) reformulates and explains the intersemi ISMs otic mechanisms in the perspectives of SF-MDA and logic in multimodal texts. In the context of this study, the ISMs are explained as below.

a. **Intersemiotic Cohesion:** In this intersemiotic mechanism, "mode choices function to make the text cohesive within and across minigenres, items, and components". This refers to the repetition of any content element in different units or part of the text. This mechanism dominantly involves co-contextualization of meaning. In addition, this mechanism can be seen as the simplest form of construction of multimodal ensemble other than use of decorative images or semiotic resources described by Daly and Unsworth (2011).

b. **Semiotic Adaption:** This mechanism involves system choices that function to make text where "the system choices from one semiotic resource are incorporated as system choices within another semiotic system". For example, an instance, explanation or option of an element is given in another scalar meaning unit of the text such 'giving the values of a parameter mentioned in a paragraph within a graphics in a different meaning unit of the text' is a typical example. This mechanism involves co-contextualization of meaning.

c. **Semiotic Mixing:** This mechanism involves system choices from different semiotic resources. For example, participants, processes, and circumstances are represented by different semiotic resources in clause level. When we note "the speed=0" we form a semiotic mixing. This mechanism involves re-contextualizing relations between the modes.

d. **Semiotic Transition:** This mechanism engages system choices which result in "intersemiotic discourse mode" that is called as macro-transition that shifts "the discourse from one mini-genre to another" (O'Halloran, 2007). Besides, these micro-transitions may take place within items. The micro-transitions are made through use of various tools, such as command, referencing, or creating a certain reading path. Liu and Owyong (2011) posit that semiotic transitions or translations (Bezemer & Kress, 2008) extends the meaning potential of scientific discourse since the type of meaning posed by the used mode changes. For example, the use of formulation or mathematical symbolism can help to re-construe the everyday experience as "scientific knowledge".

e. **Semiotic Metaphor:** This intersemiotic mechanism is based on the grammatical metaphors in linguistic mode. O'Halloran (2007) notes that the metaphorical shifts take place where "the functional status of elements is not preserved" and new semantic elements emerge. For example, a process become an entity, or a clause becomes a word group. Besides, the symbolization processes are typical examples of semiotic metaphor. Semiotic metaphor as an intersemiotic mechanism involves dominantly re-contextualizing relation in intersemiotic interactions. Liu and Owyong (2011) express those metaphors make it easier and simpler for learners to view and understand scientific content and explanation.

According to Liu and Owyong (2011), these ISMs and the resultant expanded or multiplicative meaning are commonly views as "semantic motif" for the construction of scientific knowledge in a MDST. Scientific discourse is characterized by multi-semiotic construction and resultant semantic expansions (Lemke, 1998). Lemke proposes that discourse of science is necessarily constructed by multi-semiotic hybrids due to following reasons.

a. Modes used in the discourse have their "unique functional specialization", meaning making potential, or modal affordance. For example, while language is a semiotic resource system for making categorical distinctions, visual imagery provides topologically oriented semiotic resources to formulate continuous changes. In this respect, Liu and Owyong (2011) state that, this is why "no single semiotic choice is able to afford the whole meaning of natural science".

b. The intersemiotic interactions between different semiotic resources in the discourse of science have crucial roles in the construction of scientific knowledge. The intersemiotic interaction achieves to produce meanings that any individual semiotic resource cannot do in isolation. This results in the multiplication of meaning (Lemke, 1998) which helps to demonstrate various facets of scientific knowledge.

2.2.1.4 Metafunctional Meanings Created by ISMs in the MDSTs

One strength of SFT is that it helps to analyze MDSTs in terms of metafunctionality of semiotic resources within them and the three types of metafunctional meaning each unit of these texts represent (Royce, 1998). SFT involves the similar-manner application of SFL to other semiotic resource systems. The multimodal communication involves "systems of meaning" and the act of communication involves selection from those systems in terms of what is going on the field of discourse (field, processes), who is taking part (tenor of discourse, participants) and the role assigned to language (mode of discourse, circumstances).

ISMs shed a powerful light on the functionalities of MDSTs though which social semiosis take place (O'Halloran, 2007). As stated previously, from SFT perspective, semiotic resources are multifunctional. These functions are instantiated through grammatical systems of semiotic resources which includes choice systems for ideational, interpersonal, and textual meaning. (O'Halloran, 2008)O'Halloran (2008) notes that the intersemiosis can occur in each rank in content stratum and on display stratum. Therefore, in order for figuring out how and which the ISMs work in the interactions of different semiotic resources, it is logical to consider in which stratum and rank the intersemiosis is taking place. The ISMs on the expression or display stratum demonstrated the need to consider the text structure and material basis of meaning making. This means that the choices from materiality aspects and text structure have considerable effect on the meaning derived from the text. Accordingly, the investigation of intersemiotic interactions in expression stratum leads to figure out the textual meaning conveyed by a MDST.

2.2.2 Modelling of ISMs between Languge, Visual Imagery and Mathematical Symbolism

O'Halloran (2005, pp. 167–169) explicates the semantics of ISMs and metafunctionally based systems for intersemiosis at the ranks of discourse and grammar. For the ideational metafunction, the intersemiosis is analyzed at the level of discourse and lexicogrammatical strata and corresponding ranks individually. ISMs and resulting contextualizing relations are investigated regarding the strata and ranks depicted in the Table 2.6 below.

SFMDA theoretical framework forms the basis for describing the mechanisms and the systems for ISM between language, math symbolism and math visual images in math discourse. SF-MDA as a theoretical framework provides a basis for defining and figuring out the systems for intersemiosis between language, visual imagery, and mathematical symbolism mode as modelled in the Table 2.6 below. The table is created by O'Halloran (2005) to demonstrate in which strata and ranks the intersemiotic interactions take place among three modes.

Table 2.6 Intersemiotic mechanisms taking place strata of language, visualimagery and mathematical symbolism

<table>
<tr><td rowspan="4">Stratum</td><td colspan="3">IDEOLOGY</td></tr>
<tr><td colspan="3">Generic Mix</td></tr>
<tr><td colspan="3">Registeral Mix</td></tr>
<tr><td colspan="3">Intersemiosis Minigenres,
Items, and Components</td></tr>
<tr><td rowspan="6">Content</td><td>Language</td><td>Visual Images</td><td>Math Symbolism</td></tr>
<tr><td colspan="3">Intersemiosis
Discourse Semantics</td></tr>
<tr><td>Discourse</td><td>Inter-Visual Relations</td><td>Interstatemantal Relations</td></tr>
<tr><td colspan="3">Intersemiosis
Grammar</td></tr>
<tr><td>Clause Complex
Clause</td><td>Episode
Figure</td><td>Statements
Clause</td></tr>
</table>

Table 2.6 Intersemiotic mechanisms taking place strata of language, visualimagery and mathematical symbolism (cont'd)

	Word Group/Phrase Word	Part	Expression Element
Display	IntersemiosisMateriality		
	Graphology, Typology, Graphics		

2.2.2.1 Intersemiotic Ideational Function

The intersemiotic construction of ideational meaning take place within metafunctionally based system and can be applied to science text (Halliday & Martin, 1993, p. 262). The analysis of ideational meaning proposed by SF-MDA is based on "discourse system of ideation and conjunction & continuity and grammatical system of transitivity and logico-semantic relation and interdependency". Table 2.7 below represents the ideational features in terms of a range of questions. Royce (1998) points out that the ideational meaning can be figured out by asking the text the questions shown in the table below. By the way, these questions demonstrate what the ideational meaning involves as a metafunction and what the semiotic resources within a MDST is representing.

Table 2.7 Question to multimodal texts to reveal ideational meaning

Visual, Intersemiosis, and Verbal Content	**Questions to the text for ideational meaning**
Identification	Who or what presented participants? (actor, recipients,goals). Are the participants interacting vectors?

Table 2.7 Question to multimodal texts to reveal ideational meaning (cont'd)

Activity	What factors actions taking place? Events, portrayal scene, state types of behavior. (gestures, facial expressions, stance, physical moves).
Circumstance	Where, who, with and by what means are the activities are being carried out. (setting, means, accompaniments).
Attributes	What are the qualities and characteristics of the participants? The typological and topological meaning types represented regarding participants, processes, and circumstances.

The sentence level breakdown of the elements in the visual message is done through the check with the semantically related lexical items. This means that a MDST can be translated into a linguistic monomodal text or vice versa. Visual message elements often check through aspects of the text for semantically related items. This produces series of lexical inventories of theses express the semantic relations. In this respect, O'Halloran (2007) remarks that "decision made on which lexical items to include or exclude in relation to each visual message element are based on the notion that the lexical items should be the closest semantically to each visual element or be reasonably expected to co-occur or collocate in text drawn from a particular context". Therefore, in the analysis of meaning produced from collaboration between different modes, semantically close modes are paired and emergent meaning is analyzed.

Intersemiotic interactions take place trough the operations for experiential and logical metafunctions are done through the operations described below. These operations are well examined by O'Halloran, (2007) and listed in following. In the experiential metafunction the discourse of ideation is realized through (1) transitivity relations, (2) lexicalization, visualization and symbolization, (3) semiotic metaphor, and labels in lexico-grammar stratum, and (1) juxtaposition and (2) coloring in display stratum.

Transitivity relations involves the relational processes to construct identifying relations across semiotic resources. This operation involves the determination of experiential meaning element and experiential meaning relations between them. This engages description of processes, participants, circumstances, and the experiential meaning type taking place between participants (e.g. spatial, mathematical). Halliday (2004) proposes that the transitivity system models the experience in the grammar of a clause with the semantic level categories of "process and its participants and circumstances".

The lexicalization, visualization and symbolization operation involve the systemic choices from different semiotic resource systems or modes to represent the elements determined in transitivity relations. Semiotic metaphor is a specific and characteristic ISM which involve both co-contextualizing and re-contextualizing relations where shifts in functional status of element happen and new elements emerges. The use of label involves foregrounding or locating certain elements or meaning relation. In the display stratum, for intersemiotic interactions, juxtaposition includes the use of space and positioning those create lexical, symbolic and visual relations. Also, the use of colors for experiential meaning plays a role to make continuous variation of depicted elements.

The operations done for expressing logical meaning through intersemiotic interactions involve logico-semantic interdependency, which includes cohesive and conjunctions and semiotic metaphor. The cohesive and conjunctions typically include lexical conjunctions, arrows or sequential order between different meaning units. Again, spatial positioning and coloring are employed to demonstrate logical meaning within intersemiotic interactions. The text design operations or strategies to demonstrate ideational meaning in a multimodal text are given in Table 2.8 below.

2.2.2.2 Intersemiotic Interpersonal Metafunction

In the interpersonal meaning of a text, the relations between reader/viewer of a text and producer or designer of the text are represented. In other words, how social relations are demonstrated by the specific text features. Royce (1998) states that a text can function to; give information (make statement); agreed or disagreed, (2) give goods and services (making an offer); accepted or rejected, (3) the speaker of speech can demand information (asking questions); answered or disclaimed, (4) the speaker of speech can demand goods and services; obeyed or refused (Royce, 1998). The interpersonal meaning in a text is created around these functionalities. Since, MDSTs are didactic texts, the interpersonal meaning created is mostly based in the information giver and information taker.

2.2.2.3 Intersemiotic Textual Metafunction

Royce (1998) examines the ways in which intersemiotic interaction of visual and verbal modes create the textual meaning. Examination of textual features of multimodal text involves an examination of these features of the layout or composition of the text, which allow these elements on the page to be viewed as coherent parts of the one composite text. These features are not placed on the page randomly but are places there for various purposes (the most important of which is) to convey to readers a sense of cooperation and of coherence in terms of the meaning and supporting message. The textual or compositional intersemiotic collaboration of different semiotic resources are referred to layout and design of the text. (Royce, 1998) developed a brief a framework for investigating intersemiotic interactions within the textual or compositional features of multimodal texts. In this framework, how interactions of different semiotic resources within the compositional aspect of text take place and create textual meaning.

This expression or display stratum elements demonstrated in the Table 2.8 and these can be seen as criteria when one needs to analyze the textual meaning (compositional aspects) demonstrated by a text. Furthermore, these elements are structural elements, which can be considered in text design. These elements also tools for demonstration the ideational and interpersonal meaning in a harmony and coherence for a MDST. In this respect, for example, according to White (1982, p. 127) size is an indicator of importance for an element in the text. Therefore, the designer should demonstrate the important or critical message or the aspect of the content in bigger pictures or sized in a certain mode.

Table 2.8 Analytical framework for textual meaning in intersemiotic interactions

Information valuation onthe page	Salience on the Page	Degree of Framing of Elements onthe Page	Intervisual Synonymy	Reading Path
Left/right placement (horizontal axis) Top/bottom placement (vertical axis) Balance (centerand margins)	Foregroundin gand backgroundi ng Relative sizing Tonal contrasts and variations infocus	Clear spaces or actual frame lines Visual verbal bleeding Run-around margins Gutters	Degrees of semblance in form andacross modes	The impactof potential reading paths.

2.2.3 Scalar Hierarchy and Analysis of Meaning Units in MDSTs

A MDST utilizes more than one semiotic resource project its meaning. A semantic unit in a MDST should not seen as a form rather it should bee viewed as a unit of meaning. The SF-MDA approach for multimodal texts involves formulation of hierarchies such as items and components where larger scalar units provide integrity contexts for smaller units. Baldry and Thibault (2010, p. 144) developed conceptual and methodological approach and practice to analyze multimodal texts. They view that multimodal texts are clusters of items, objects, and elements which are “spatially proximate thereby defining a specific region or sub-region of the page as a whole”. The clusters within a multimodal text are different regarding scale where larger scales items consist of interactions of smaller scales and these hierarchical positions are termed by sub-clusters, clusters, superclusters. Scalar hierarchy principle helps to model the intersemiotic interactions occurring in different parts or units of the text. This helps to divide a MDST into smaller meaning units and analyze the meaning making resources in smallest meaning unit of a MDST and evaluate emergent meaning. O’Halloran (2007) combines the scalar hierarchy principle of Baldry and Thibault's (2010) to investigate multimodal mathematics texts which is mainly made of language, visual imagery, and mathematical symbolism similar to science texts. She posits the formulation of “scalar hierarchy” for multimodal texts that enables for analyzing the “differentiated kinds of units” and the relations between them at different text levels. The formation of scalar hierarchy and the scales (meaning units) in a multimodal text are visualized in the Figure 2.9 below.

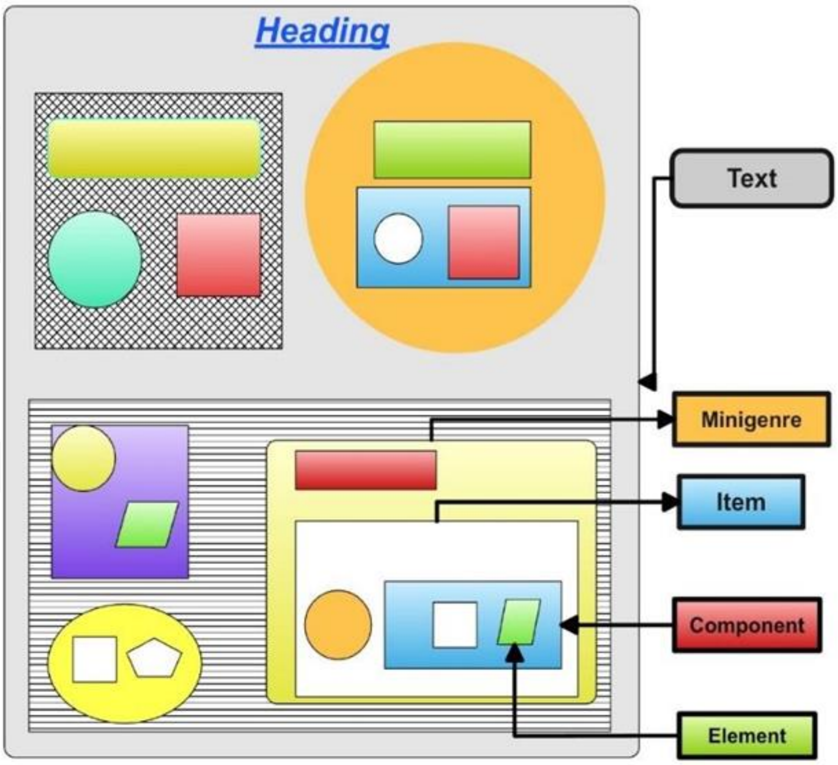

Figure 2.9 A Typical text structure in scalar hierarchy

These different scales of clusters interact with each other through “meaning comprehension” principle. The meaning comprehension principle is a principle of economy or semiotic economy whereby patterned multimodal combinations or integrations of visual, verbal, mathematical resources “on the small, highly compressed scale provide semiotic models of the larger, more complex, realities that individuals have to engage in” (O’Halloran, 2007, p. 90)(O’Halloran, 2007, p. 90).

The meaning comprehension principle which lies in the sense of economy that basically refers to “visual scanning of these smaller scale patterns may take more seconds and places no burden on processing” (O’Halloran, 2007, p. 90). O’Halloran states that, “information is scanned in complex texts through the assimilation of lower scale clusters which are contextualized at higher level”. She adds that, therefore, the spatially separated and semantically related texts are “indicators of semiotic economy”. This semiotic economy principle is barely works at science discourse where various modes operate together to represent and communicate scientific knowledge. Spatial distinctness in science discourse is one factor, which ensures the successful operation other meaning comprehension principle. Baldry and Thibault (2010) formulation of scalar dimensions of multimodal interplay can be used productively to investigate the contextualizing relations produced from the ISMs. Accordingly, the scalar dimension principle helps to analyze multimodal texts as in separated but related sub-scale constituent parts. The determination of scalar dimensions makes it easier to figure out the stratum and rank-shifted elements and observation of intersemiotic interactions taking place.

The contextualizing processes in science discourse seems to unfold in particular sequence proposed by the scalar hierarchy approach. A MDST is assumed to mini-genres, items, and component as the scalar unit. Components are assumed as the clause level scales that are made of elements. Items are seen in the clause complex level, which encompasses more than one component. Mini-genres are the characteristic parts of a text, which are at least paragraph level. Mini-genres could be explanations, narrations, questions, or solutions. The transitions and relation are made between different scales may be done with linguistic or visual imagery elements such as conjunctions, arrows, lines etc. The possible interactions taking place among different hierarchical units of text are visualized in the Figure 2.7 below.

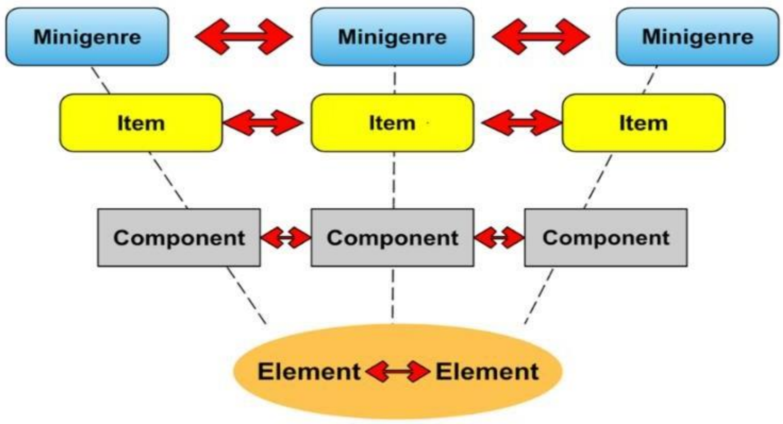

Figure 2.10 Interactions in scalar/hierarchical units in multimodal texts

These transitions are done in the interaction of different semiotic resources. This refers to intersemiotic interactions where meaning is multiplied are done through this transition at different levels of scalar hierarchy. For example, in the component level, there are interactions of elements and if those elements are represented with different semiotic resources, the intersemiosis take place between the elements and the semiotic resources complement each other to produce a meaning at component level. In this respect, the potential of existence of contextualizing relations in science texts is quite high since at least three modes are combined to form components, items, and mini-genres.

To sum up, the ISMs and stratum/rank principles of SFT help to reveal how the metafunctional meanings realized by different semiotic resources across different stratum and rank-shifted choice systems. Besides, the scalar hierarchy principle helps to divide a multimodal text into smaller units and analyze the forms of semiosis form lowest scale to whole text in a bottom-up approach. However, the stratum systems and scalar hierarchy are not unrelated, rather they are interrelated. The modelling of strata and corresponding scalar hierarchy units where intersemiotic interactions is visualized in the Figure 2.11 below.

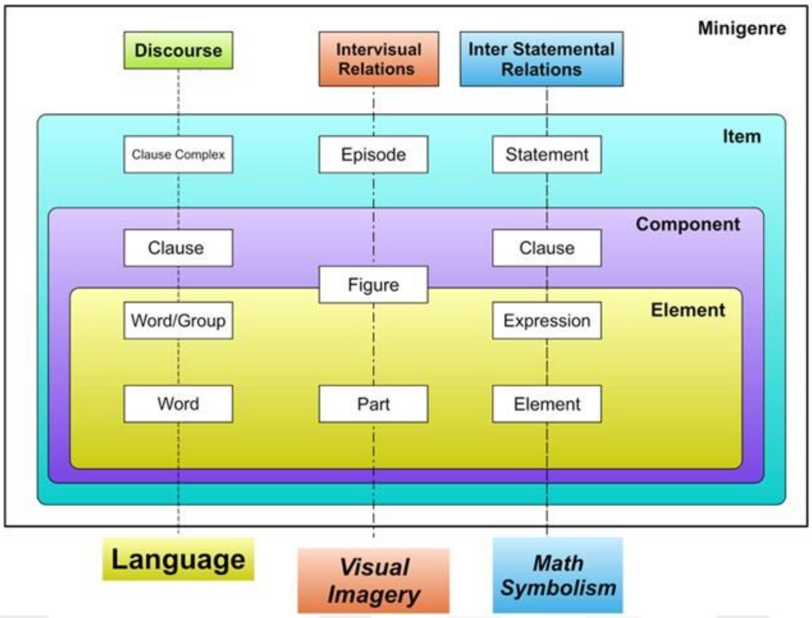

Figure 2.11 Modelling of ıntersemiotic ınteractions in each stratum and scalar level for language, visual ımagery, and mathematical mode

2.2.4 Data Analysis Framework and Procedure for Multimodal Didactic Science Texts

The conceptual and theoretical lenses and backdrops mentioned above inform the data analysis framework of the study. This involves perspectives from social semiotics multimodality, SFT, and VTL. Discourse analysis methods help to analyze the meaning making processes in different contexts and different communities. The analysis of science texts is to investigate the semiotic construction of scientific knowledge in the perspective of science discourse, which is phylogenetically developed as multimodal. This discourse involves multisemiotic system choices to demonstrate scientific knowledge. A single multimodal text is viewed as a realization of a particular contextual configuration of field (processes), tenor (participants) and mode (circumstances) which forms the thematic formation, and which can be analyzed through thematic pattern strategy to figure out the DRAs demonstrated by this text. Decomposition of text within the scalar hierarchy into the meaning units and relating these meaning units to create logical action sequences creates semiotic economy in the text. The ways of relating is well-explained by Tang et al. (2019). Additionally, the intersemiotic and modal interactions become more observable more open for evaluation with the use of scalar hierarchy principle. This helps to map the intersemiotic mechanisms taking place in the texts. Accordingly, the modelling of the ISMs helps to envisage how the meaning is contextualized and expanded in the related meaning unit. These together helps to reveal how meaning in the meaning units are realized and instantiated.

Main aim of data analysis is to investigate; (1) which semiotic resources are used and combined to realize ideational, interpersonal, and textual meaning within the text, (2) which intersemiotic mechanisms take part in semiosis, and (3) how successfully the used semiotic resources in intersemiotic interactions realize ideational, interpersonal, textual metafunction (compositional features) in the object of learning.

For investigation of ideational meaning, this study focuses on the transitivity systems and logical relations in the different scalar parts of the text (or in different strata of the text). This analysis involves figuring out of participants, processes, circumstances, and the experiential meaning types taking part in the scalar parts of the content. After figuring out of these semantic stratum elements, which semiotic resources are individually or together used to demonstrate these semantic stratum elements are analyzed in different scalar parts of the text. Relying on the idea of mixed-mode semiosis of Lemke (2000) and variation theory of learning, how successfully different semiotic resources are used and combined to enhance meaning making of scientific knowledge. The analysis of interpersonal meaning of the text involves the following purposes. First, it is well known that the analyzed text is a didactic text and there is a teacher and learner social relationship between the designer and viewer/reader of the text.

Furthermore, in such a relation the designer of text convinces learners to understand which information pieces are more important which are less, or which are foregrounded, and which are peripheral. This involves the criticalness hierarchy of disciplinary relevant aspects and their demonstration within the different scalar parts. The criticalness hierarchy is observed mainly in foregrounding of some aspects and relatively backgrounding of other aspects and locations of these aspects through compositional features in the text. Therefore, the analysis of size and location of the scalar parts provides implications for the interpersonal meaning demonstrated by the text. This analysis is also supported by interviews with the designers of texts to deeply understand their pedagogical aims.

The textual meaning in a text, functions to make the text have a coherent compositional structure in demonstrating the ideational and interpersonal meaning. Compositional features defined by Royce (1998) above are analyzed to evaluate textual metafunctions of texts.

In the lights of the theoretical backdrop for the MDST, the analysis and evaluation can be briefly expressed as following. In the MDST analysis the first step is divide the text into scalar units. Next step is analyzing the paradigmatic and syntagmatic system choices in demonstrating ideational, interpersonal, and textual meaning. In this way, the analysis yields that, which design choices (meaning making resources) are employed to demonstrate scientific knowledge in MDSTs. In this study, since the MDSTs are analyzed at component level, the text is analyzed at component level for paradigmatic choices. For the syntagmatic choices, the compositional aspects of whole text and the relations between different components are analyzed. The text analysis strategy involves following steps;

- **a.** Dividing the text into microgenres, items, components, and elements.
- **b.** Determining the transitivity system elements in the clause level stratum in component scale and determining DRAs.
- **c.** Figuring out the semiotic resources and modes used and interacted.
- **d.** Figuring out the meaning types demonstrated by modes and semiotic resources inside them.
- **e.** Determining if the implicit and explicit variations are created around the critical DRAs.
- **f.** Observing how the intersemiotic interactions take place between components, items, and microgenres.
- **g.** Figuring out the transitions between different scalar parts and how these parts are related with each other.
- **h.** Labelling of critical hierarchy with the help of data gathered through interviews.

i. Analysis of compositional features of the text to evaluate the textual meaning represented. These compositional features are placement of text elements, foregrounding/backgrounding, degree of framing, heading/subheading, and relative sizing.

Figure 2.12 summarizes and visualizes the MDST analysis strategy derived from the theoretical background above.

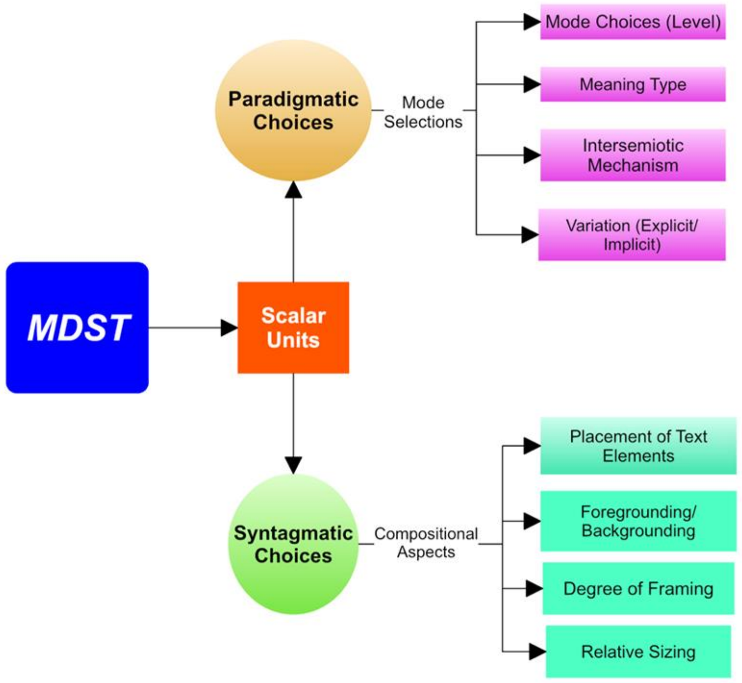

Figure 2.12 Overview of MDST analysis strategy

2.3 Theoretical Framework of PD-MUST and Theoretical/Draft PD-MUST

As said earlier, this study aims to develop a specific intervention model (PD-MUST) which aims to promote ISToGs' MDST text design competency. So far, in the theoretical framework part, the conceptualization, design, and analysis frameworks of MDSTs are explained. This part involves the theoretical framework for pedagogical approach of design principles, learning goals and learning activities. At the end of this part, the draft intervention model (draft PD-MUST) with its design principles and hypothetical learning trajectories are explained. The draft design principles include the initial theoretical underpinnings and initial practical advisory knowledge for a well-grounded problem solution and design propositions. These design principles are based on the existing theoretical knowledge about the issue and underlying concepts, previous studies and their solution propositions, and information gathered the contexts where the problem resides.

2.3.1 Draft Design Principles

2.3.1.1 Theoretical Draft Design Principles

a. Learning is a mediated action. Learning is a design, and it includes internal and external design of representations.

b. “Learning”, consequently, is defined as an increased capacity to use signs and engage meaningfully in different situations. Learning is here understood as a process of interpretation and sign production. The use of modes and media in processes of interpretation and identity construction is here central for the understanding of learning activities.

c. Learning is a dynamic re-representation process in which students re-represent the information and presentations that teachers present in semiotic resources in the classroom.

d. Discourse of science and science texts are inherently multimodal and each mode deployed in a text has their own characteristic meaning making potential.

e. Multimodal learning environment requires representational competent teacher. The teacher is expected to harmonize and orchestrate semiotic sources and modes effectively in order to design a meaningful teaching experience to engage, motivate, and educate students.

f. Since, semiotic resources, modes, and design characteristics of a text affect the internalized meaning and externalized meaning, they have a potential to impact on the creative learning resources.

g. Students are active designers of their learning processes. They view, manipulate, interpret, and transform teacher’s available multimodal representations into new and meaningful ones.

h. The semiotic construction of scientific knowledge involves use of diverse modes and semiotic resources and teaching and learning in the science classroom is a multisemiotic experience.

i. A didactic science text has paradigmatic and syntagmatic system choices in design. These system choices are shaped by discourse of science and pedagogical intentions of science a teacher.

j. Concepts, processes, entities, and circumstances are demonstrated through semiotic resources and the choices in use and compositional arrangement of these resources affect demonstrated meaning and affect meaning making of the content.

k. Semiotic resources in a science text have topological and typological kind of meanings and the combination of these meaning types helps to contextualization of meaning.

l. Students are active designers of their learning processes. They view, manipulate, interpret, and transform teacher's available multimodal representations into new and meaningful ones.

m. The knowledge units in a science text do not have equal importance and there is hierarchy of criticalness of different knowledge units of a text.

n. The semiotic resource and mode choices and composition of them should be done according to the critical hierarchy and the discernibility of knowledge units can be arranged accordingly.

o. Having multimodal didactic text design competency may be gained through specifically developed interventions which enables teachers transform their knowledge to creative products.

2.3.1.2 Practical Draft Design Principles

a. While the teacher is preparing learning resources, s/he should provide well-designed sign system of information instead of well-designed information.

b. Teachers should present conceptual knowledge to students by designing them in multimodal texts or by harmonizing and organizing available designs

c. Recognizing the forms and functions of different semiotic resources and modes and make conscious system choices when required.

d. Deployment of semiotic resources that have different meaning types (topological and typological) to demonstrate a meaning unit helps to contextualize meaning. This increases the richness of learning resources and concretization of the content.

e. An understanding of the meaning making potentials of different modes helps to effective use of semiotic resources in designing a text, so, increasing the meaning making potential of the text.

f. The design of a didactic text is driven by the learning goals and intentions.

g. The choices of semiotic resources and modes are done according to the affordance or meaning making potentials of these resources.

h. Determining the important and critical aspects of a content parallel to learning intentions and embrace a social semiotic reasoning while designing a text to teach the content.

i. The compositional aspects including dimensions of text elements, locations, and the relation between these elements should be arranges regarding the hierarchy of criticalness among the different units of the texts.

j. Not only dividing the text into different meaning units helps to demonstrate the relation between different pieces of knowledge, but it also increased the semiotic economy in the text.

k. An intervention that aims to train science teachers to promote MDST competency may involve awareness, recognize, overt instruction, and feedback learning activities.

2.3.2 Draft Intervention Model

The interventional model is the main product of this study and provides actionable knowledge to solve determined problem. The intervention model is developed as a training program (PD-MUST) that intends to improve MDST competency of science teachers of gifted students. Main elements during the development of draft intervention model are the pedagogical approach of the intervention, the learning goals, the learning activities to address the learning goals, and the assessment and evaluation strategies. The model as a training program is developed within a pedagogical approach, which is called design-based pedagogy. The design-based pedagogy (Cope & Kalantzis, 2015; Jewitt, 2008; Kress & Selander, 2012) mainly involves the transformation of knowledge and learning by design.

2.3.2.1 Pedagogical Approach of HLTs

Pedagogic Approach of Activities:

Pedagogic approach based on learning by design Cope and Kalantzis (2015). Workshop activities involve mostly implicit interventions. The pedagogical strategies are based on transformation of knowledge that engages representational design practices. The focus is on design and contextual use of the designed texts. We follow The New London Group (1996) and Cope and Kalantzis's (2015) how of pedagogy and Tytler et al.'s (2013) "Representation Construction Pedagogy". Transformation of knowledge is expected to take place through following stages of how of pedagogy. How of pedagogy is explained through Lim's (2018) propositions in relation to our multimodal text production and analysis framework social semiotics systemic functional approach in Table 2.9 below.

Table 2.9 Practical explanation of how of pedagogy and SFT approach

Dimensions	Knowledge Processes	Pedagogical Features in the Systemic Functional Approach
Situated Practice	Experiencing (the known and the new)	• Genre-based • Authentic Texts • Collaborative Learning
Overt Instruction	Conceptualizing (by naming and with theory)	• Explicit Teaching
Critical Framing	Analyzing (functionally and critically)	• Inductive Learning

Table 2.9 Practical explanation of how of pedagogy and SFT approach (cont'd)

Transformed Practice	Applying (appropriately)	• Artefact Making • Performance in actual situations.

- **Situated Practice:** This part involves the rich experiences of what exist and what their features are without any explicit information. The learners are immersed in the environment and social context, and they try to recognize what is there and what they function for. By this way, the learner starts to build her understanding about the phenomena and the internalizes through individual experiences.
- **Overt Instruction:** In this phase, Lim (2018) expresses that, "useful practices from didactic pedagogy are applied, the explicit teaching of the terms and concepts through the introduction of the meta-language for the specific multimodal text is a feature of the systemic functional approach". The focus in the dimension of overt instruction is for students to "learn to use abstract, generalizing terms through drawing distinctions, identifying similarities and differences, and categorizing with labels" (Cope & Kalantzis, 2015, p. 19).
- **Critical framing:** Critical framing is done through inductive learning, where learners are guided in the viewing and analysis of multimodal texts so as to "identity features and patterns" that are later supported and explicitly demonstrated by teachers as scientific concepts. Students work across a selection of multimodal texts designed by teachers, and are guided/scaffolded through an inductive process to identify and relate the textual features to the typical functions they serve, as well as surface and associate the multimodal strategies to the typical effects they realize. The process where students examine and questions the texts and "examine cause and effect, structure and function" helps them to improve their reasoning in critiquing representations which is later

verified and strengthened through the critical framing of the teacher. (Cope & Kalantzis, 2015, p. 20). Through this active and inductive learning, students are given with help and scaffolded to see the multimodal texts.

- **Transformed practice:** The dimension of the transformed practice engages students to learn by putting into effect "experiential, conceptual or critical knowledge" (Cope & Kalantzis, 2015, p. 21). This requires students to design and construct representations or multimodal texts as way or strategy to both build and demonstrate scientific knowledge. Besides our pedagogical implications are also informed by Tytler et al. (2013) who developed "a representation construction pedagogy". We express a combination of The New London Group'S (1996) and Tytler et al.'s (2013) strategies as below. The table demonstrates the adaptation of design based pedagogical approach with teaching sequences of multimodal text design.

Table 2.10 Representation construction pedagogy and how of pedagogy

<table>
<tr><th colspan="3">Representation Construction Pedagogy of (Tytler et al., 2013)</th><th rowspan="3">"How of Pedagogy" Correspondence (The New London Group, 1996)</th></tr>
<tr><td colspan="2">Activity Category</td><td rowspan="2">Explanation</td></tr>
<tr><td>Main Category</td><td>Sub-Category</td></tr>
</table>

Table 2.10 Representation construction pedagogy and how of pedagogy (cont'd)

Teaching sequences are based on recognition and sequences of representational challenges: To actively engage and explore, and create ideas about a concept, students are expected to construct or design representations.	***a) Clarifying the representational resources underpinning keyconcepts***	Key concepts, critical aspects, and representations to show them are the initial duty for teachers for representational work in the planning phase.	Situated Practice
	(b) Establishing a representational need:	The sequence and composition of representations involve demonstrations in which student discern the problematic and critical aspects of DRAs.	
	(c) Coordinating/aligning student generated and canonical representations	The interplay between teacher-designed representations and student externally designed representations "where students are challenged and supported to refine and extend and coordinate their understandings".	

Table 2.10 Representation construction pedagogy and how of pedagogy (cont'd)

2. Representations are explicitly discussed: The teachers have multiple roles including leadership, scaffolder, and negotiator that includes discussions with students.	***(a) The selective purpose of any representation:***	To make the DRAs more understandable, students need to discern and experience multiple aspects and facets of a concept.	Overt Instruction
	(b) Group agreement on generative representations:	Students need to be guided and scaffolded when they criticize available representations to reach a solution.	
	(c) Form and function:	Teachers need to clarify the forms and functions of representations in a timely manner.	
	(d) The adequacy of representations:	The representations designed by both teachers and students need ongoing assessment.	

Table 2.10 Representation construction pedagogy and how of pedagogy (cont'd)

3. Meaningful learning: Teachers need to provide "strong perceptual/experiential contexts" to increase student engagement and agency during design activities.	***a) Perceptual context:***	The representational practices and designs should be done as immersed to "strong perceptual context" such as hands on experiment.	Critical Framing
	(b) Engagement /agency:	Students need to be immersed learning activity sequences which provide "personally meaningful and	
		challenging, through affording agency and attending to students' interests, values and aesthetic preferences, and personal histories".	
4. Assessment through representations:	During representational practices in classroom, formative and summative assessments are required. These provide students with generating and interpretingopportunities. The ongoing assessment ofadequacy of representation is needed.		Transformed Practice

In this study, the draft intervention model consists of two separate hypothetical learning trajectories (hereafter HLTs). An HLT is designed according to above mentioned parts of how of pedagogy. Parallel to approaches and learning strategies mentioned above, a model of HLT is developed to support transformation of knowledge during learning and learning by design. This strategy is also developed parallel to revised version of Bloom's taxonomy (Anderson & Krathwoll, 2001) where the information is transformed to creative learning products. The Bloom's taxonomy is visualized below. Therefore, we developed a HLT having following parts or learning activities. Awareness, recognize, overt instruction, design, feedback, and re-design (if necessary). The tools, applications, and their pedagogical functions are further explained in following sections.

Table 2.11 The form and elements of HLTs in draft intervention model

Step	Instructional Goal
Awareness	This step is done through interviews where the researcher asks questions about the learning goals. Themain aim is to reveal their existing knowledge and create explicit motivation for shaping their thinking inthe next step. The awareness step is the first part of design-based learning since it reveals the existing knowledge and competencies and imitates inquiry andself-criticism toward targeted learning.
Recognition	In this step, the learner experiences different science texts that are at different mode level and variation level. Discussion questions are directed to the participants as they experience different multimodal texts. This step aims to help learners recognize the differences of texts in terms of semiotic resources thetexts have, the mode differences, and the compositional features of texts. The discussion data is recorded and further analyzed.
Overt Instruction	This step includes the explicit teaching. The researcher prepares instructional videos, which haveboth information about the learning content and demonstrative text design activities.
Design	In this step participants design multimodal sciencetexts given with certain content and learning goals.Participants design multimodal texts in by using certain production tools and applications that are further explained further.

Table 2.11 The form and elements of HLTs in draft intervention model (cont'd)

Feedbacks	In this step, the researcher analyzes and evaluates participants' texts. The evaluation is made also for theHLT itself. The data gathered from the interview and learner texts designs help the researcher also evaluatewhether there is a problem or insufficiency with the both content and function of any part of the HLT. If any problem observed with the HLT, the problematic part is improved and participants are asked to design new multimodal text in the next iteration. If a problem is observed at individual level, participants are individually given with feedbacks and asked to design new texts. The multimodal text analysis and interviews with participants on their designs enact the data analysis. After the analysis and evaluation, the researcher gives feedbacks to the learner.
Re-design	After the feedbacks, the learner is given with a new topic and content and asked to design new multimodal science text by considering the feedbacks. The learner designs again and the researcher analyzes and evaluates.

2.3.2.2 The Model of Learning Objectives

The draft intervention model is an integration of three HLTs, which have their own learning goals. The main aim of the draft intervention model is help participants proceed from factual knowledge level to creating their own multimodal texts. This knowledge transformation is considered to take place in hierarchical step-by-step progress which is modelled by a certain model of learning goals. The revised form of Bloom's taxonomy (Anderson & Krathwoll, 2001) is a comprehensive model, which is "the intersection of the Cognitive Process Dimension and the Knowledge Dimension". The transformation of knowledge in design-based pedagogy involves the knowledge dimension and each shift or transformation engages changes in cognitive domain. The knowledge dimension which includes both major types and sub-types is presented in table 2.12 below (Heer, 2012). The cognitive processes dimension with the categories and cognitive processes is given in Table 2.13 which is adapted from Anderson and Krathwoll (2001).

Table 2.12 The knowledge dimension of MDST competency

Concrete knowledge	**>>>>>>>>>>>**		**Abstract knowledge**
Factual	**Conceptual**	**Procedural**	**Metacognitive**
Knowledge of terminology Knowledge of specific details and elements	Knowledge of classifications andcategories Knowledge of principles and generalizatio ns Knowledge of theories, models,and structures	Knowledge of subject specific skills and algorithms Knowledge of subject specific techniques and methods Knowledge of criteria for determining whento use appropriate procedures	Strategic knowledge Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge Self-knowledge

Table 2.13 The cognitive processes dimension mdst competency

Lower Order Thinking Skills			**>>>>>>>**		**Higher Order Thinking Skills**
Remember	**Understand**	**Apply**	**Analyze**	**Evaluate**	**Create**
Recognizing Recalling	Interpreting Exemplifying Classifying Summarizing Inferring Comparing Explaining	Executing Implementing	Differentiating Organizing Attributing	Checking Critiquing	Generating Planning Producing

(Heer, 2012) provides a three-dimensional representation (model) of the revised taxonomy of the cognitive domain. The intersection of cognitive process dimension and knowledge dimension is visualized in below in the figure 2.13 below.

Figure 2.13 Revised Taxonomy of Bloom and related domains

The draft intervention model is consisted of two HLTs having the pedagogical structure described above. Each HLT has its own learning goals and assessment strategies. The learning goals, implementation structure and steps are explained above and learning goals of each HLT are given in their sections below. The integrated structure of draft implementation is visualized below in Figure 2.14.

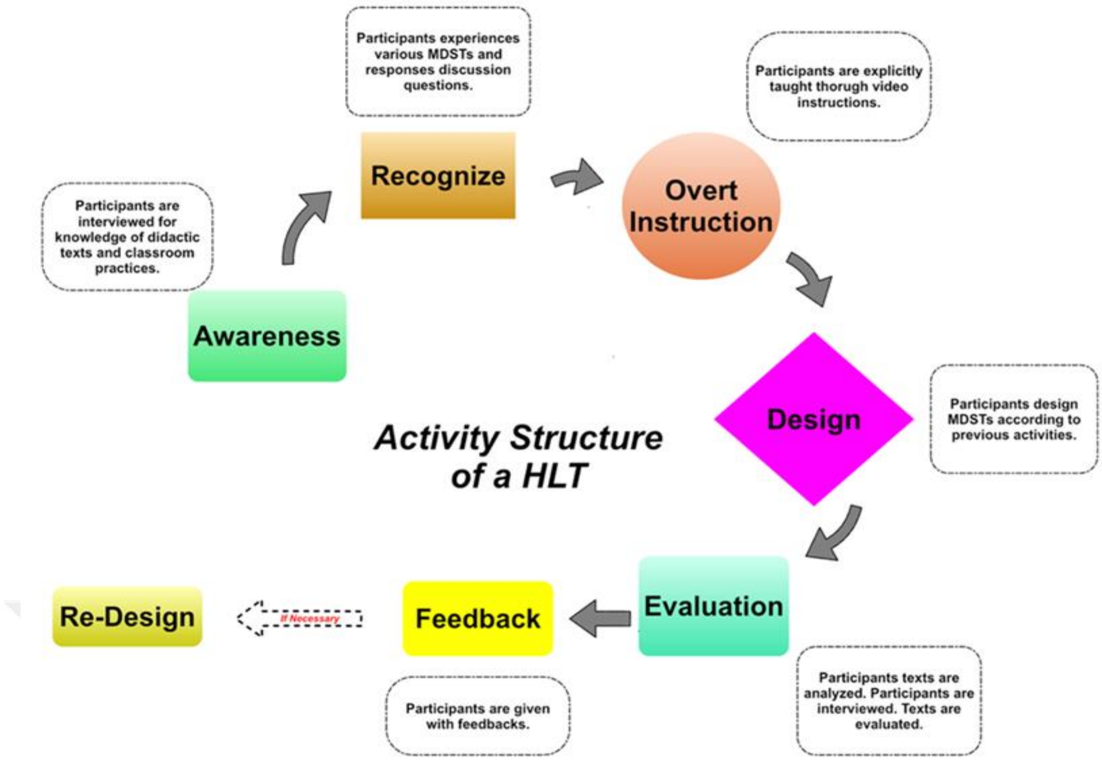

Figure 2.14 The ımplementation structure and procedure of an HLT

The intervention model is a combination of two HLTs (HLT1 and HLT2). The implementation of the intervention model is done in this order visualized in figure 2.15.

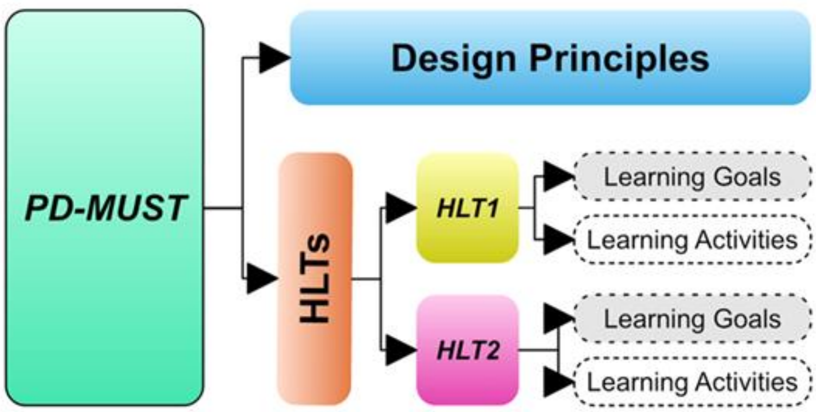

Figure 2.15 The intervention model

2.3.2.3 Hypothetical Learning Trajectories

a. **Hypothetical Learning Trajectory 1 (HLT1):** This HLT focuses on the paradigmatic dimension and system choices in designing MDST. In this regard, it involves how meaning making take place (forms of semiosis) the multi-semiotic construction and de-construction of scientific knowledge, multimodality, multimodal discourse of science and design of multimodal texts. The hypothetical learning trajectory and the learning activities planned for achieving learning goals are planned as in below before the implementation. The learning goals of HLT1 is given in below.

Learning goals. Teachers will be able to;

- Identify, classify, and differentiate participants (concepts and entities), processes, and circumstances of a science content.
- Identify, classify, and differentiate meaning relationship types between the participants taking part in the content.
- Recognize, classify, and differentiate typological and topological meaning types of disciplinary relevant aspects.
- Implement, select, re-construct, and coordinate semiotic resources and resource types that offer ease of understanding (disciplinary and pedagogic affordance).
- Identify, classify, use, select mode concept and mode types.
- Categorize, contrast, and distinguish the affordance of meaning making power (affordance) of mode types.
- Use, differentiate, organize, suitable mode to represent the type of meaning and meaning relationship.
- Understand and explain concept of multimodality
- Identify, understand, use, organize, and generate multimodal texts

  - **Awareness Step:** In this step, a semi-structured interview is done with each participant. Researcher tries to ask about the existing knowledge about factors that influence meaning making of science content, tools and mediums used to make meaningful communication of scientific knowledge in the science classroom, their representational practices, how they design and use science texts in science teaching. Next, their opinions and ideas about multimodal nature of discourse of science and their use of modes to demonstrate scientific knowledge are asked. The interview questions can be seen in Appendix A.

- **Recognize Step:** In this step researcher develops four science texts about same content (Kinetic Energy) at different mode levels. In the first text, the content is given in monomodal structure (language mode). The second text consists of language mode and mathematical mode. In the third text, language, mathematical, and image mode used. However, image mode is used to demonstrate topological meanings of entities. In the last text, all three modes are used and the image mode additionally demonstrated spatial relationships among the concepts. All texts have different semiotic resource choices. Texts are given in Appendix B.
  - In the activity the texts are given step by step and in each step, participants are asked with discussion questions about the used semiotic resources, modes, and the meaning-potential of the demonstrated text. Participants gives open-ended responses. After participants experienced all the texts, evaluation question asked. The questions include the effect of used modes and semiotic resources on meaning making of the content, the effect of these resources of meaning on the learning products of students and the creativity of these learning products, and their choice of them with the rationale. The text are given in digital forms and the application enable participants give both written and speech responses. In this step, participants experienced, discussed, criticized, and evaluated texts that have different mode levels and semiotic resources to demonstrate same science content.
- **Overt Instruction:** This phase aims to provide explicit knowledge about the meaning making, semiotic construction of scientific

knowledge, and multimodal science text design. Since the implementation is conducted in online platform, the researcher prepared an instruction video. The video explains the related facts, concepts, processes in detain and provides a meta-strategy. Participants access the video and watches any time they want.

- **Design:** Following the video overt instruction, participants are asked to design two multimodal science texts. The content of the texts is given in monomodal format. Participants are expected to design these multimodal texts by considering the information and strategies given in the video. The topic of the first text is the "photosynthesis" and second is "electric resistance". The video was still accessible. The texts are designed in digital platforms until the pre-given deadline.
- **Assessment, Evaluation, and Feedback:** In this phase, participant designs are collected and analyzed. The analysis is done with SF-MDA described in theoretical framework part. Furthermore, an interview with participants are done to deeply understand their designs and how this part of intervention (HLT 1) functioned, which parts are successful and which parts need to be improved. The interview functions to both evaluate participant designs and the process. After analysis of data obtained in this phase, participants are given with feedbacks on their texts and asked to design texts on another content. Furthermore, if the implementation needs to be improved or developed, additional intervention is done in the next iteration.

b. **Hypothetical Learning Trajectory 2 (HLT2):** This hypothetical learning trajectory focuses on pedagogical aspects of text design. In HLT 1 participants enhances their competencies on selecting and determining meaningful resources for design the text. This HLT aims to help to learn how to use and deploy them within the pedagogical concerns. As said before, the VTL helps to reach this aim in designing of multimodal didactic texts. The learning goals of this HLT are given in the table below. Teachers will be able to;

- Identify, contrast, and differentiate disciplinary relevant aspects of the object of learning or content.
- Recognize, compare, differentiate Important, critical, characteristics or aspects within the disciplinary relevant aspects.
- Classify, organize, and plan the hierarchical order of the information that the content has as theme (focal), peripheral, and margin according to the criticalness level.
- Implement, organize, and produce dimensional, spatial, and relational text composition arrangement between representations that represent the features or aspects according to the criticality- importance hierarchy.
- Create explicit variation around critical aspects to make critical aspects more understandable.
  - **Awareness:** In the awareness phase, interviews are done to figure out how the participants are aware the effect on the text structure on meaning derived from the text. Furthermore, questions about their teaching practices on this issue asked. The interview questions can be seen in Appendix A.
  - **Recognize:** In this phase, two differently designed multimodal texts are presented to participants about two different subject. These texts have same text elements (semiotic resources and modes) but in different arrangement. The first two text are about the "pitch" subject. The second two texts are about the subject of "covalent bonding". The first two texts are presented in live interview and participants views asked about their pedagogical values and meaning making potentials about the focus or critical aspects of the content. In designing the texts, same semiotic resources are chosen. In the first, the selected elements are randomly located, their relational dimensions kept same, and no connectional tools used between the different units of the text. The design of second text is informed by the strategies given by VTL, therefore the dimensions, locations, relations between different parts are arranged the hierarchy of

criticalness of the knowledge pieces in the texts. Participants give their responses both written or speech. Texts are given in Appendix C.

- **Overt Instruction:** In this step, the researcher prepares an instruction video. The video contains information about VTL's pedagogical suggestion in designing didactic texts and provides strategies for multimodal text composition. Explicit information strategies are given with examples. The video also includes ample examples of multimodal text designs. Participants are asked to watch the instructional video until a pre-determined deadline.
- **Design:** In this phase, participants are asked to design a multimodal text regarding the variation meta-strategy included in the video instruction. Participants are given with a subject of "active transport". Participants design the texts in the digital format in given time gap.
- **Assessment, Evaluation, and Feedback:** In this phase, participant designs are collected and analyzed. The analysis is done with SF-MDA described in above. Furthermore, an interview with participants are done for deeply understanding designs and how this part of intervention (HLT 2) functioned, which parts are successful and which parts need to be improved. The interview functions to both evaluate participant designs and the process. After analysis of data obtained in this phase, participants are given with feedbacks on their texts and asked to design texts on another content. Furthermore, if the implementation needs to be improved or developed, additional intervention is done in as next iteration.

Given with this theoretical background, the PD-MUST is developed as draft (theoretical) which includes the pedagogical approach, learning goals, learning activities (HLTs and the activities in each HLT), and design principles of PD-MUST. In short, the draft PD-MUST includes the draft design principles and HLTs (HLT1 and HLT2) that are tested and developed through design experiments. The effects of draft PD-MUST on MDST design competencies of ISToGs are observed, PD-MUST is further developed and presented as a final product for enhancing MDST design competencies of ISToGs. The effects of PD-MUST are observed in the lights of empirical findings that demonstrates the MDST design competencies of participant ISToGs.

Figure 2.14 below briefly demonstrates the target pedagogical competency for ISToGs and the target professional development program which is an intervention model (PD-MUST) that this study intends to develop. As said earlier, the conceptualization of MDST design competency involves the conceptualization of MDSTs, design framework for MDST design, and analysis framework for MDSTs. PD-MUST involves the intervention model for promoting MDST design competencies of ISToGs.

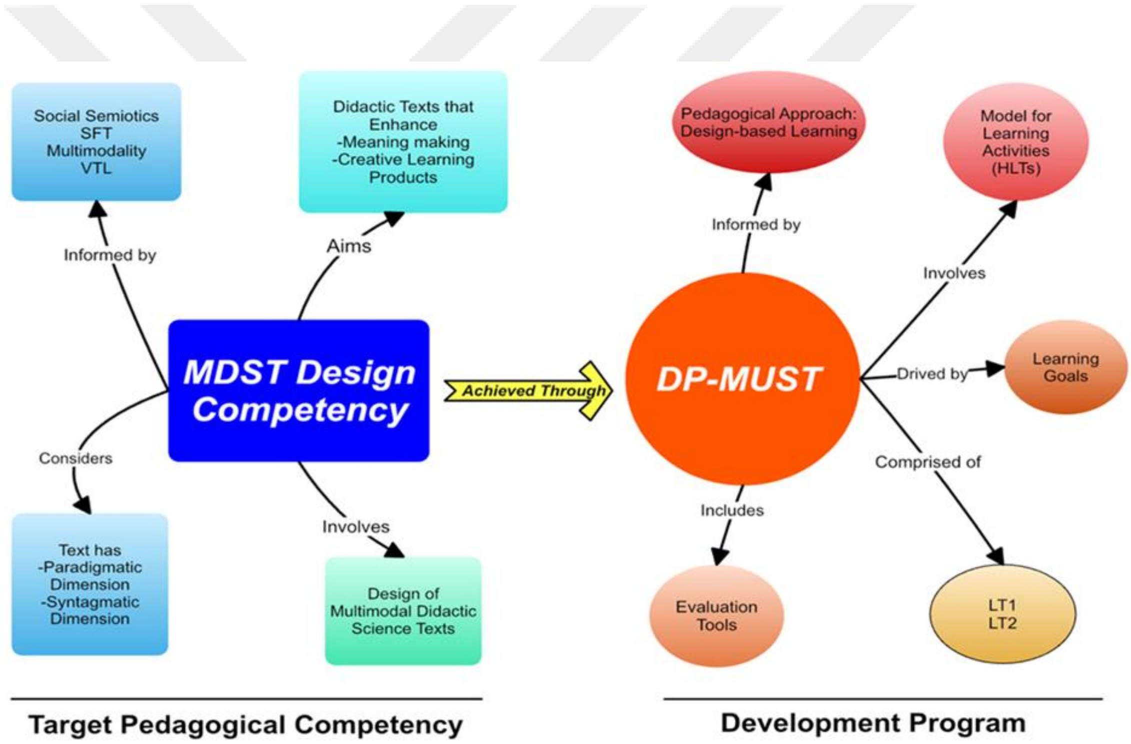

Figure 2.16 Overview of MDST design competency and PD-MUST intervention model

3
METHOD

3.1Research Design

The methodological design of this study is educational design research (hereafter EDR). EDR investigates solution proposals to complex educational problems through systematic examination and development of an intervention (Bakker, 2018). According to Plomp (2010, p. 9) EDR is "the systematic study of designing, developing and evaluating educational interventions, – such as programs, teaching-learning strategies and materials, products and systems – as solutions to such problems, which also aims at advancing our knowledge about the characteristics of these interventions and the processes to design and develop them". It also contributes to our knowledge of the qualities of these interventions and the characteristics of these design and development processes. Furthermore, Phillips and Dolle (2006, p. 287) define EDR as "a genre of research in which the iterative development of solutions to practical and complex educational problems also provides the context for empirical investigation, which yields theoretical understanding that can inform the work of others".

EDR aims to produce "actionable knowledge and theories of action" (Bakker, 2018, p. 46). According to Bakker (2018), these productions are also advisory in nature that are summarized and presented in terms of design principles, conjecture maps, or hypothetical learning trajectories. It is suggested that, in a research the production of any of them depends on the aims and focus of the research. In this study, since design of a specific type of learning process and instruction (PD-MUST) is the aim, the advisory knowledge is aimed to produce in the formats of design principles and hypothetical learning trajectories. This study is qualitative descriptive and interventionist. The descriptive part engages to reveal awareness and existing competency levels of ISToGs in designing MDSTs. The interventionist side involves changing participants' current level regarding sets of skills including their awareness, recognition, design competencies, and evaluation about MDSTs used in teaching practices in gifted science classroom.

Figure 3.1 below demonstrates the methodological aspects of the research which is explained in detail in the following parts.

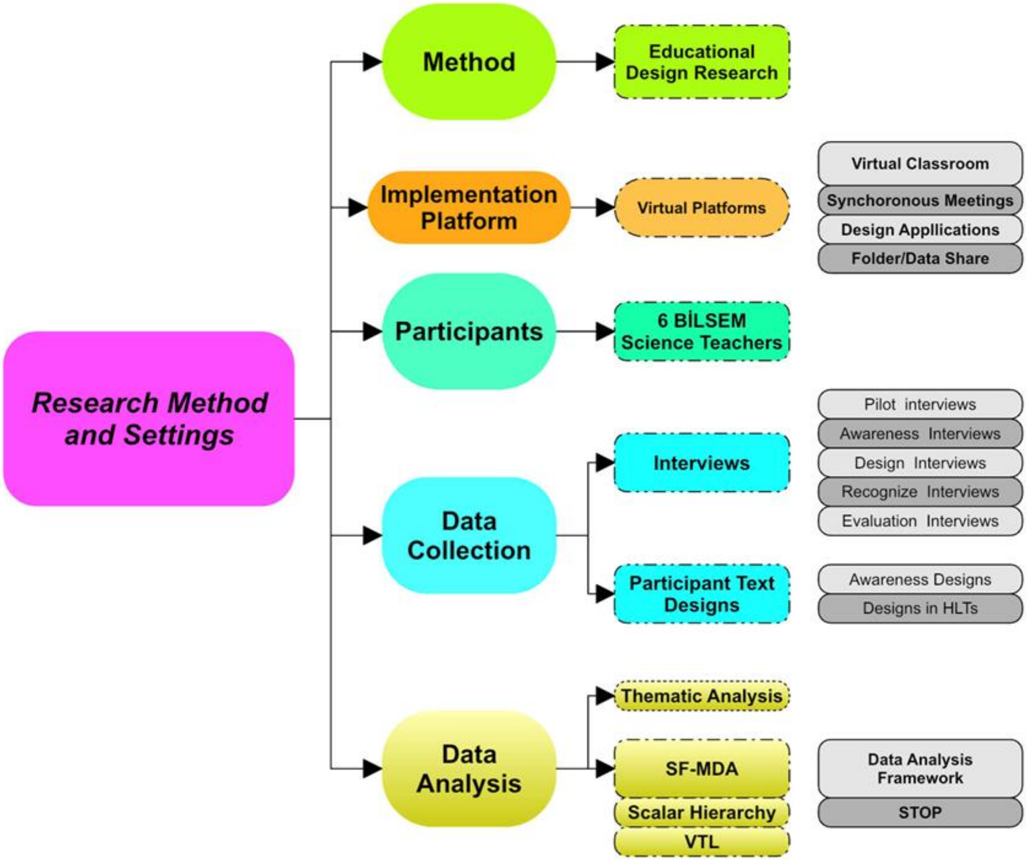

Figure 3.1 Overview of the methodological aspects of the study

3.2 Procedure and the Phases of the Research

The models for EDR give much prominence on the cyclic processes and iterations. Through these cycles and iterations, the proposed design principles, and intervention model (PD-MUST) is developed in real settings with actual practitioners. Design research is generally conducted in three main phases (see Figure 3.2). These main phases are defined as (1) preparation and design (initial phase), (2) implementation (development including intervention, enactment, teaching experiment, or trial), and (3) retrospective analysis, and redesign (Bakker, 2018). In the first phase, the problem is determined, and the solution proposal is theoretically developed as draft. The second phase involves the development or prototyping phase where the draft solution proposal is tested in actual settings through interventionist iterative cyclic design experiments. The effect of the solution proposal (PD-MUST here) on the target competency (MSDT design competency of ISToGs here) is observed through empirical findings. The final step engages evaluation where the developed product and development process are evaluated regarding efficiency, implications, and replicability. In the following part, the procedure of this research is explained within the phases of EDR.

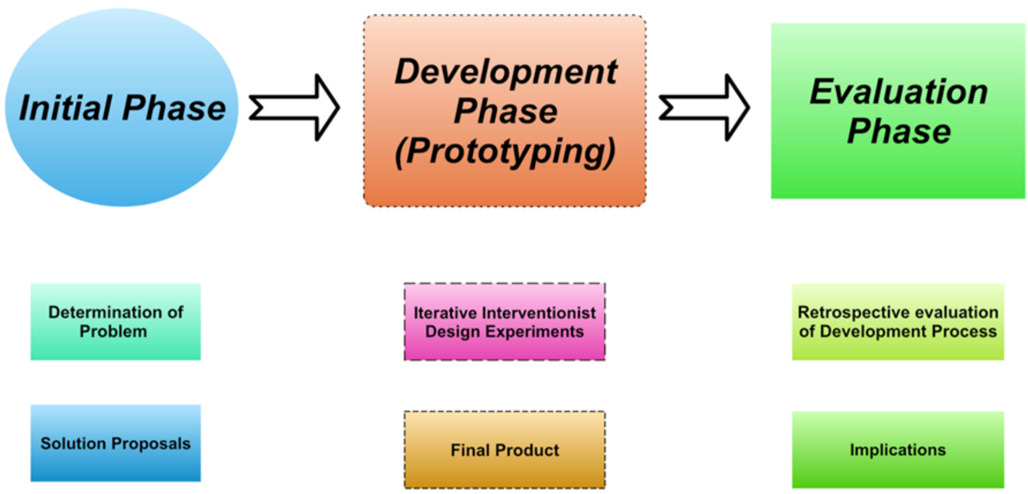

Figure 3.2 Phase of the research

3.2.1 Phase 1: Initial Phase (Analysis and Exploration)

This phase mainly includes determination of the problem and development of draft design principles and draft intervention model. The draft intervention model includes draft HLTs with design principles. To make these determinations possible there are a few steps a researcher follows and does. According to McKenney and Reeves (2012), the preparation and design phase consists of two sub-phases which are (1) analysis and (2) exploration. These sub-phases have their own steps and procedures.

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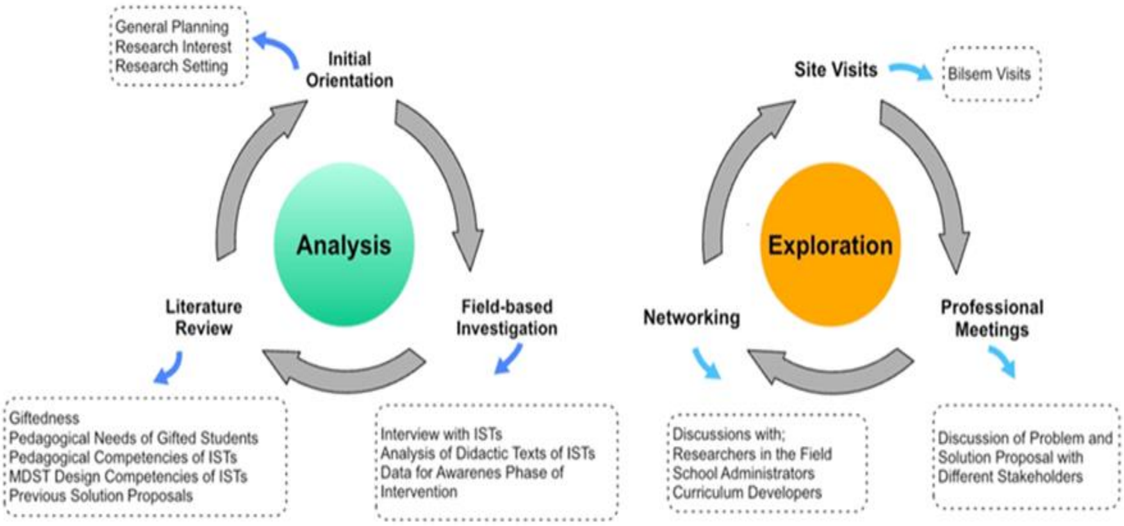

Figure 3.3 An overview of initial phase of the research

3.2.1.1 Analysis

The analysis step involves initial orientation, literature review, and field-based investigation. This sub-phase functions to build starting steps of the research and gather first literature-based and field-based information. This is the first cycle in this design research and the constituents helps to define the problem.

a. **Initial Orientation:** McKenney and Reeves (2012) posit that the initial orientation aims to address this question: What do we want to know (1) about the problem, (2) about the context, and (3) about stakeholder needs and wishes? The first aspect includes ": What is the current situation? What is the desired situation? and What is already known or suspected about causes for this discrepancy?". The remaining two aspects engage the information about stakeholders, physical context, educational context, and the viability. Pedagogic competencies ISToGs regarding MDST competency are at the wide focus of this study. In particular, this study focuses on the MDST competencies of science teachers. The initial orientation of the study is started with this concern. The assumption is that these competencies should be at a level required by the design-based pedagogy, and initial orientation phase is the preparation phase for gathering information about the assumed problem, the context, the needs and requests of science teachers of gifted/talented students. This preparation involves mainly what we want to know and how we can act. In this respect, it was decided to review relevant literature and do field-based investigation to figure out the situation about the assumed problem or interest.

b. **Literature Review:** Literature review is an effective way to figure out what was done before for the assumed problem. In this step a rigorous review of the literature is done. The researcher focuses on the previous researches and their solution propositions about the problem. (McKenney & Reeves, 2012) note that the literature review "provides ideas which can help shape data collection" and "it can be used to identify frameworks". After initial preparation, the literature review was done to the concepts and theoretical perspectives about the problem, what has empirically been done for in the field. For this aim, reviews on studies on pedagogical approaches in gifted education, studies conducted on design based-pedagogy, teacher competencies in science classroom of gifted learners, and finally the empirical studies on developing and learning material- design skills and competencies of these teachers. The literature review yielded that there is a paucity of studies on professional developments of in-service science teachers of gifted students. It was observed that there are numerous studies on classroom representational practices of science teachers (i.e. Jaipal, 2010; Jewitt et al., 2001; Oliveira et al., 2014; Patron et al., 2017) but no such studies observed for the science teaching of gifted learners. This issue is also discussed in literature review section. At the end of the literature review, knowledge about representational competency and multimodal text design obtained. The literature review demonstrated the gap about the specific professional development program or training program on the text design and multimodal didactic texts.

c. **Field-Based Investigation:** The field-based investigation helps researchers to be "immersed in the problem context" and, in this way, the existence in the field will trigger to think about the situation (McKenney & Reeves, 2012). The field- based investigation affords researchers the opportunity to become somewhat immersed in the problem context and to begin to develop and refine ideas about why things are as such. The field-based investigation can be done through various methods including observations, interviews, tests, questionnaires, document analysis. Afterwards the literature review and field- based investigation, the researcher refined the questions and selected strategies determined in the initial orientation. After the rigorous review of literature, there made several observations on the representational practices in science classrooms and how the teachers effectively perform these practices. The field-based investigation helped to observe the current practices about the problem. Therefore, the investigation provided valuable information to sharpen the margins of the problem. Besides observation, there made interviews with science teachers as practitioners about their routines and practices.

- **Awareness Interviews with ISToGs:** Here, participants joined awareness interviews on the effects of resources used in teaching activities in the meaning of scientific content and the formation of creative learning products, on the sources that make sense, types of text, types of meanings and modes that enable the communication of scientific knowledge, and semiotic construction of scientific knowledge. For the interview questions, see Appendix A. These interviews were made to figure out what teachers focus on before and during teaching, what factors they consider as critical in meaning making of content, the importance given to the texts and design of these texts during teaching and learning, and their knowledge about the meaning elements in a science text. This interview mainly figured out their awareness and practical routines about the multimodal texts and meaning making. Open-ended semi-structured individual interviews were done with six teachers.

- **Collection of Didactic Science Texts:** The field-based investigation also includes data about teacher's didactic science texts that are used in the classroom. Each participant provided didactic texts that they use in their actual teaching practices. This data set is collected before the implementation of PD-MUST. The data is presented in the finding section. In short, in the field investigation step, field observations are made, interviews with teachers are done and teacher's didactic text are collected and analyzed. In this way, the status in actual setting with actual practitioners is revealed. The knowledge obtained in the literature review, the data collected during interviews, teachers' texts used in the science lessons helped to precisely determine the problem.
- **The Problem statement:** At the end of this step, it was determined that the level of awareness in the role of didactic texts on the meaning making of science concepts and their role on the creative learning products quite low for the observed and interviewed in-service science teachers of gifted/talented students. The data in this step also demonstrated that, teachers' competencies in selecting and designing multimodal science texts are limited and needed to be improved. After the determination of the problem, the draft (theoretical) PD-MUST is developed as a solution proposal. This solution proposal is presented to the stakeholders in exploration step.

3.2.1.2 Exploration

According to McKenney and Reeves (2012) the exploration sub-phase aims to find "new ways to look at problems and their solutions". This is expected to take place after the analysis of sub-phase in which the conceptualization of the problem and the context emerge. Much of the exploration in design research is informal. It is also generally an ongoing process, which takes place in the background while the more formal research activities (e.g., literature review, field-based investigation) remain at the forefront. The strategies for exploration include site visits, professional meetings, and networking. Site visits are done to deeply understand the problem; professional meetings are done to gather views of practitioners, and networking helps to get information or data from diverse stakeholders pertaining to the problem.

While analysis focuses on the exact determination of the problem, the exploration phase aims to look for finding solutions to problems other than what theories or literature recommend. This is done for presenting problem solutions to diverse stakeholders pertaining to problem and gathering their views. In this step visits to several schools of gifted students (BILSEM) were done and views

a. **Site Visits:** In this step, visits to several schools of gifted/talented students (BILSEM) were done and views of teachers and administrators are taken for the possible ways to solve the problem or enhance existing competency level in designing multimodal didactic science texts. These talks were informal. Teachers and administrators admitted the importance of the problem, but they stated that this problem can be solve through a professional development or training program/workshop which are not merely based on theoretical information but based on the learning by doing.
b. **Networking and Professional Meetings:** In this step, the researcher participated diverse academic conferences and meetings particular to education of gifted students and teacher education. What is more, to get views and recommendations of academicians studying in the fields of giftedness and education of gifted/talented students were takes. These views were generally on the necessity of the professional development of teachers for increasing the content knowledge of students and reinforcing creative learning products. These people generally pointed out the specific training program to solve the determined problem.

3.2.1.3 Solution proposals to solve the problem.

At the end of the analysis and exploration steps of the first phase of this design research, the exact definition of the problem is done after a precise literature review, field observations, and interviews with teachers and analysis of teachers' didactics texts designed and used by teachers. Afterwards, possible problem solutions were gathered from diverse stakeholders (teachers, administrators, and researchers in the field) gathered. Mintrop (2016, p. 219) expresses that the main purpose of a design development in a design research is to "discover an ensemble of tools, materials, tasks, organizational structures, and any other activities that are apt to set in motion a process of learning that improves on a focal problem of practice". The final step of this phase is to develop the draft solution proposals as actionable knowledge format defined by Bakker (2018). This development is based on previous and current theoretical and practical knowledge. Therefore, relying on the theoretical framework of this study, literature review, and the information obtained through the analysis and exploration steps, draft design principles and draft intervention model is developed. The theoretical bases of these two kind of actionable knowledge constructed on the theories of inter-individual learning (Vygotsky, 1978) meaning making , multimodal communication (Jewitt et al., 2016; Kress, 2010) social semiotics (Halliday, 1978; Hodge & Kress, 1988; Lemke, 1990) (Halliday, 1978; Hodge & Kress, 1988; Lemke, 1990), systemic functional theory (Halliday, 2004), Variation Theory of Learning (Marton & Tsui, 2004) 5A creativity model of Glăveanu (2013) and Cattell-Horn-Carroll theory of cognitive abilities and intelligence (Schneider & McGrew, 2012). The draft PD-MUST with its theoretical background was given in section 2.3.

3.2.2 Phase 2: Development Phase (Prototyping)

In this phase, the design principles and draft intervention model which are initially developed and mapped to address the problem are tried in actual settings to test if they are meeting the intended outcomes and continuous development is done in iterative cycles until the intended functions are observed. This phase is called a “design and construction” by McKenney and Reeves (2012) and they proposed that they are “systematic and intentional, but they also include inventive creativity, application of emerging insights, and openness to serendipity.” They add that, through this phase initial design solutions (draft design principles and draft intervention model) gradually become “refined, pruned, and operationalized”.

Bakker (2018) posits that draft intervention model as design requirements serve guidance on “what is to be accomplished (the learning goals) and the draft design principles as design propositions inform “how that can be done and why”. The draft intervention (and integrating HLTs) serve “the practical goals EDR by helping to sharpen the focus of an intervention and provide solid grounds upon which design choices can be made”.In the progressive iterative cyclic processes, the theoretical and practical models of the design (draft design principles and draft intervention model) are put into use and at the and the design principles and intervention model flesh out as the main products of the research.

The revision and evaluation of the design principles and intervention model after each iteration can be done through various strategies and methods. Mainly the findings including, such as, participant performances, participant’s responses, participant generated learning products in each iteration and check if the intended learning goal is achieved in desired level. Therefore, each iteration involves same logic but somewhat different intervention process. In the end of the prototyping phase the products of a design research is shaped and emerge as (for this study) design principles and intervention model for solving the determined educational problem.

The function of an HLT at this stage is primarily to guide the enactment of the trial or teaching experiment and guide the data collection about phenomena in which you are most interested – related to mediating processes, mechanisms, and outcomes in your HLT. In development phase where participants actively join the interventionist design experiments. Because the intervention phase involves, certain responsibilities for participants, timetable, and use of certain applications, tools, and virtual platforms participants needed to be informed before starting implementation. Therefore, an introduction meeting was held.

3.2.2.1 Initiation/Introduction Step

Since the development phase involves the experimentations with participants, an introductory meeting is necessary before starting the activities. In this goal, an introductory meeting was arranged, and the participants are informed with the process, calendar, and responsibilities of both participants and the researcher. Furthermore, because the implementation is done through digital platforms and communication technologies, it is necessary to inform about the digital tools and applications and give detailed information about use of them. The digital tools include a virtual classroom having design tools, application for live video meetings, data storage, and instant communication. The participants are informed with detail. After the introduction meeting, the implementation process started parallel to calendar. Since the use of applications and design tools were vital for this remote training program, the researcher prepared a video that includes detailed demonstration of the uses of these applications and platforms.

3.2.2.2 Prototyping /Development Phase:

This phase is the implementation phase for the theoretically developed PD-MUST which is initially draft intervention model. Therefore, the theory meets with the practice in the development phase. The theoretically developed product is put into use and check for how it works. If there is a problematic part, the implementation is developed in the progress. The development starts with the initiation step where the participants are informed with process, responsibilities, calendar, and the tools and applications that are used in learning and design activities. The experimentation phase follows the initiation step. The experimentation step includes the implementation of HLTs as cyclic iterations. A HLT is a cycle of learning activities, and each iteration involves a developed form or version of HLT. In each iteration, the developed form is examined and until the satisfactory point of development the iterations continue.

This prototyping phase usually continues until the PD-MUST reaches the desired level of competence as a completed product. Therefore, at this stage, applications were carried out in a cyclical process. The assumed procedure of implementation is visualized in Figure 3.4 below.

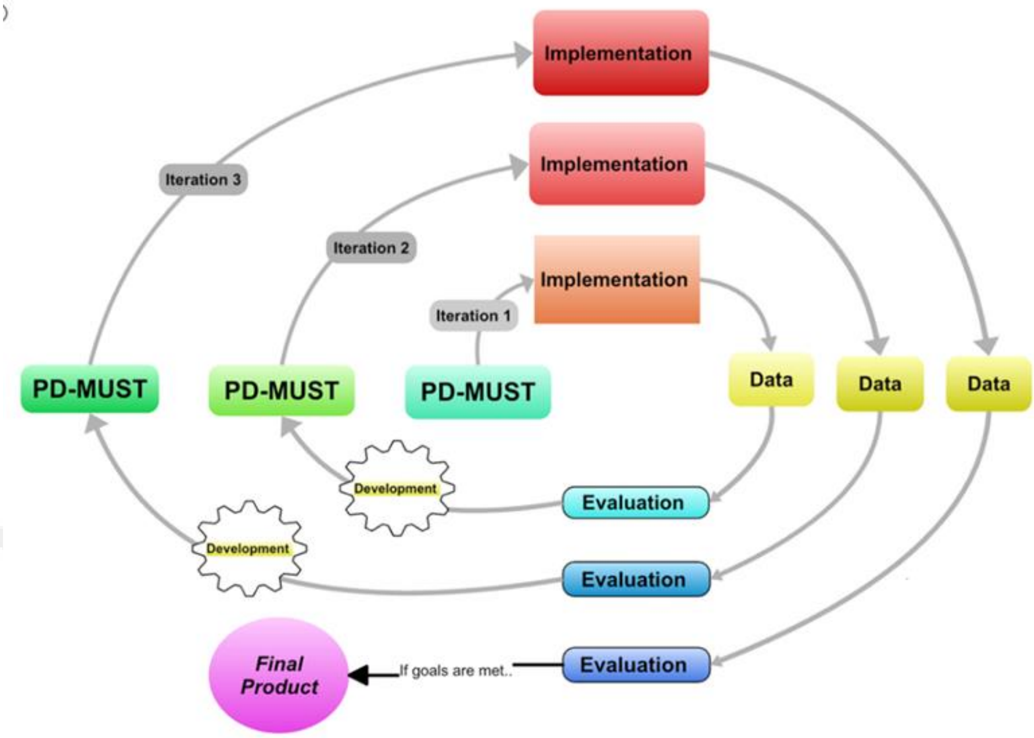

Figure 3.4 The implementation form of ıntervention phase (Development)

a. **Development of HLT 1:** The structure and procedure of HLT 1 is explained in the draft intervention model section 2.4. Developments of this HLT took two iterations. The iterations and developed parts are given in following parts. The development process of HLT1 is visualized in Figure 3.5 below.

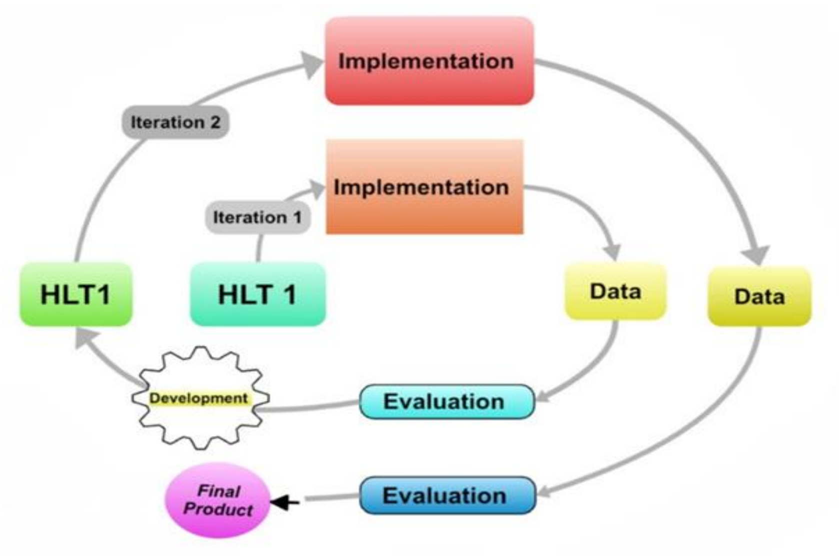

Figure 3.5 Development process of HLT1

- **First Iteration of Hypothetical Learning Trajectory 1**

  The first iteration of the HLT1 involved following steps, which are visualized in Figure 3,6. As said earlier, HLT1 focuses on the paradigmatic dimensions in designing MDSTs. The awareness step was held in the interviews made in the initial phase, the recognize phase where different mode level texts of same content provide teachers and recognize discussion interviews are done. The texts are in Appendix B and the interview data is provided in findings Section 5.2.1. In the overt instruction activity, a video instruction on meaning making (semiosis), communication of scientific knowledge, multimodality, modes and affordances, and first part of multimodal text design strategy. The instruction video includes paradigmatic choices (ideational meaning) in design in didactic MDSTs that have high meaning making potential (affordance). In this part, participants are given with explicit knowledge. In the design part, participants are given with a topic (Photosynthesis) and they are assigned to design a didactic text. After participants designed texts, the texts are analyzed and an evaluation interview was done. In the end, it was observed that the mode level and the contextualization of meaning in the text are not at satisfactory level and it was understood from interviews that video instruction is insufficient in designing text. Therefore, a handbook including the video topics with further exemplary cases for text design prepared. In the end of the first iteration of HLT1, the overt instruction activity is supported with a handbook. Participants are given with feedbacks and doing one more iteration was decided.

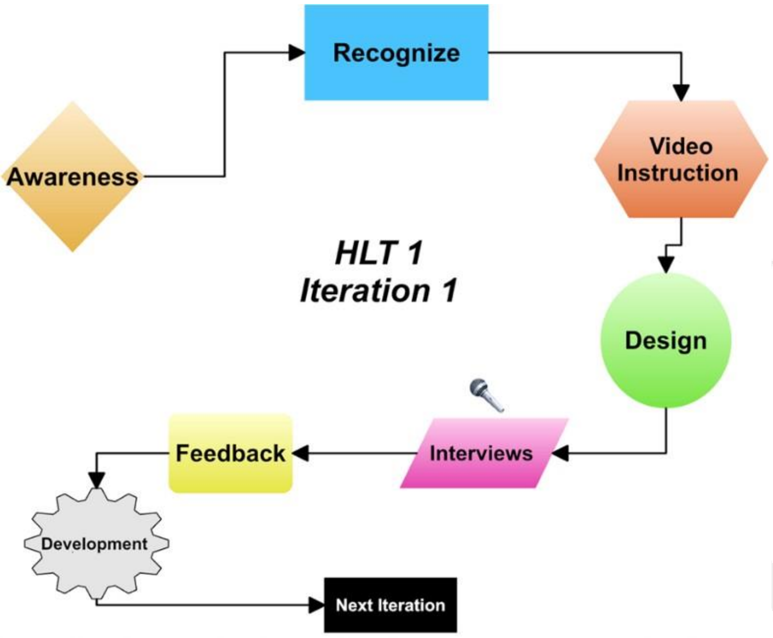

Figure 3.6 Implementation procedure of iteration 1 of HLT1

- **Second Iteration of Hypothetical Learning Trajectory 1**

  In this iteration, participants are suggested to watch the video again and read the handbook. Afterwards, they are given with a new text design assignment. The subject of the text was Ohm's Law. Participants designed the texts. After the analysis of the texts and design interviews, from the data of the texts and interviews, it was observed that participants are at satisfactory levels to meet the regarding learning goals. Some participants were given with minor feedbacks. In the end of this iteration, the first part of the implementation model was developed. The developed part involves learning goals, the content, learning activities, and assessment tools.

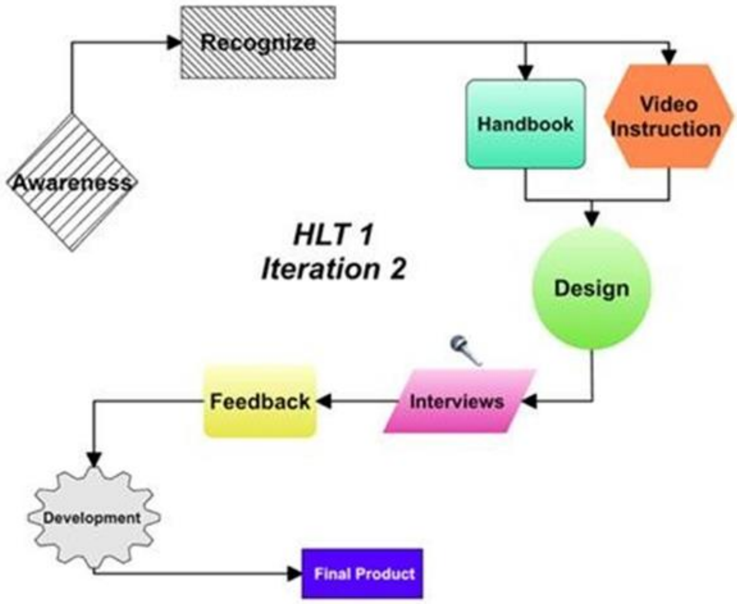

Figure 3.7 Implementation procedure of iteration 2 of HLT1

b. **Development of HLT 2:** As said earlier, HLT2 focuses on the syntagmatic dimensions in designing MDSTs. HLT2 was done in three cyclic iterations. The development process of the HLT2 is visualized in Figure 3.8.

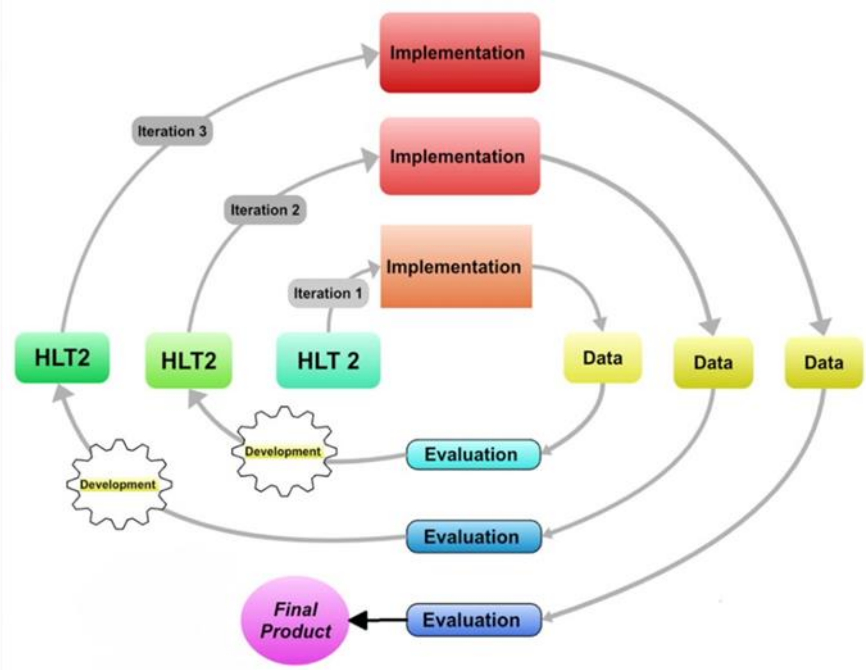

Figure 3.8 Iterative cycles of development process of HLT2

- **First Iteration of Hypothetical Learning Trajectory 2**

The first iteration included awareness, recognize, overt instruction, design, design interview, and feedback steps (see Figure 3.9). The awareness step included interview questions on the knowledge and actual classroom practices regarding the aims of the HLT. In the recognize activity, participants experienced two multimodal texts of same content (see Appendix C) and discussion questions were asked. All two texts include same semiotic resources and modes, composition of one text was done randomly, and the other was designed according to ideas drawn from VTL. The data of these interview is given in the findings section. In the overt instruction activity, participants are provided with a video instruction including exemplary cases of text design. This video is prepared by the researchers as the intervention content and provides explicit knowledge on the compositional features (syntagmatic choices and textual meaning) multimodal didactic science texts. After the overt instruction phase, participants are given with a text design assignment that had the topic of “Active Transport”. After the analysis of the texts and design interviews, it was observed that participants were generally unclear with the relation between compositional features of text and the VTL as a pedagogic strategy. In this step, participants are expected to design the compositional aspects with a pedagogical strategy that is informed by the VTL. Participants were given with feedbacks and the implementation is developed for further iterations.

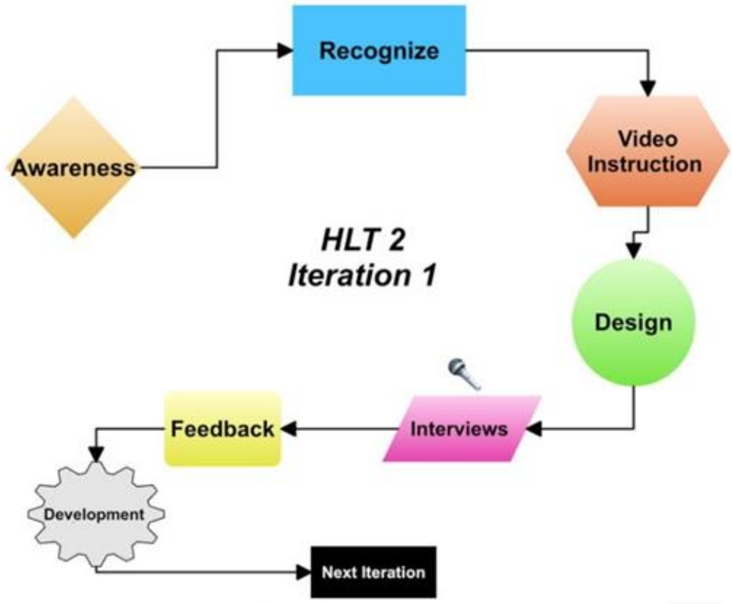

Figure 3.9 Implementation procedure of iteration 1 of HLT2

- **Second Iteration of Hypothetical Learning Trajectory 2**

  In the second iteration of HLT2, participants are provided with handbook similar to the second iteration of the HLT1 (see Figure 3.10). In this handbook, multimodal text composition features for didactic texts that have high meaning making potential and text composition as meaning making resource is synoptically introduced with ample exemplary cases. After the preparation of the handbook, participants are given with new text design assignment. Participants designed the texts, and the texts are analyzed. With the help of design interview data, it was observed that most of the participants were still unclear about the “criticalness hierarchy and the discernibility of critical aspects of the content”. Most of the participants put the heading into the center of the texts instead of the critical aspects. Participants are given with feedbacks, and it was decided to organize an individual live instruction in the virtual environment. The live instruction session was the further development for HLT2.

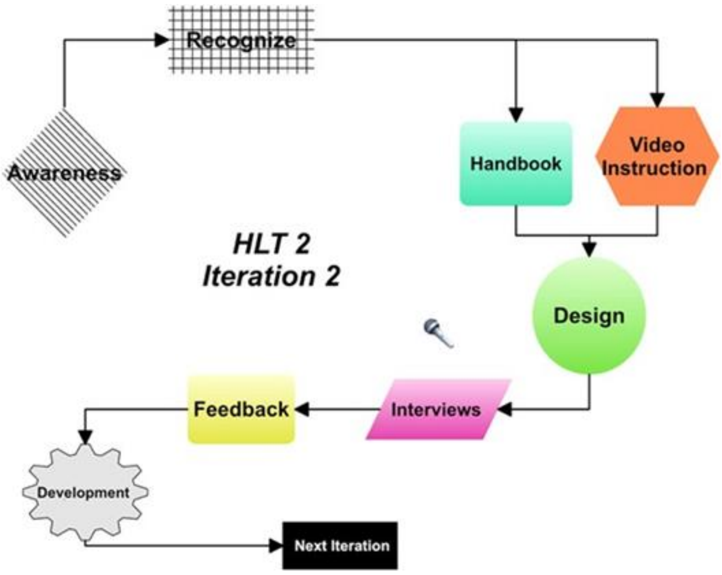

Figure 3.10 Implementation procedure of iteration 2 of HLT2

- **Third Iteration of Hypothetical Learning Trajectory 2**

  In the third iteration of HLT2, roughly 20 minutes live instruction of multimodal didactic text composition informed by VTL was given with the use of participants previous texts was done. These live instructions were done individually. After the live instructions, participants are given with new text design assignment that has the content of "Pulleys". Afterwards, the participants designed texts and texts are analyzed and evaluated with the text design interview data. Results demonstrated that, the texts have satisfactory meaning making potential and design features determined by the theoretical assumptions of this study. The two dimensions of MDST design (paradigmatic dimension of HLT1 and syntagmatic dimension of HLT2) were observed to involve sufficient quality. The development of this HLT was ended and final product for HLT2 with learning goals, content, learning activities, and assessment tools were developed.

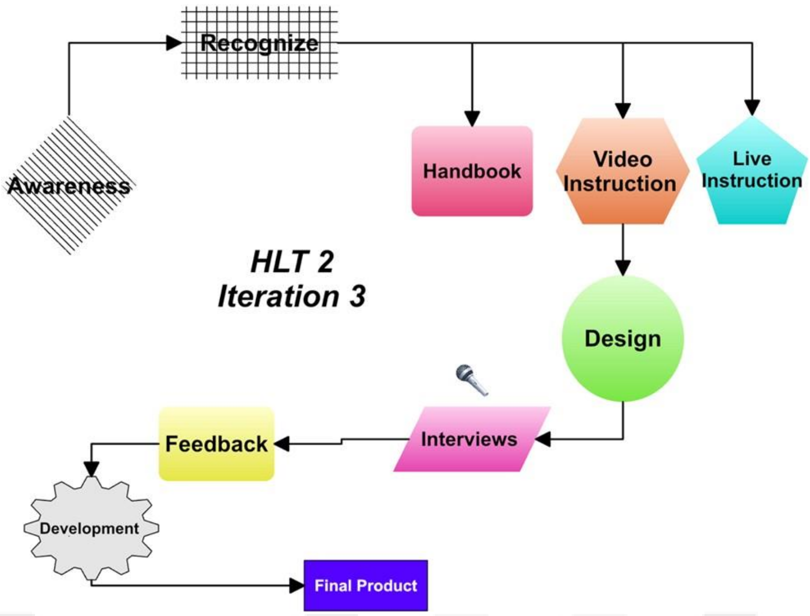

Figure 3.11 Implementation procedure of third iteration of HLT2

The success in achieving learning goals was monitored in individual progress in developing a meta-strategy for designing MDSTs. Since the developing or dependent variable is a meta-strategy, the topic of the designed texts needs to be diverse. The competency level in applying this strategy is followed in the gradual success in designing and the underlying pedagogical design intentions revealed through the design interviews. The overall progress and individual progress demonstrated the function of the intervention model.

3.2.3. Phase-3: Evaluation

The last phase of a design research is the evaluation phase. In this evaluation phase, from the beginning of the preliminary phase to the end of the development phase, collected data are analyzed overall in a retrospective approach. At this phase all data obtained from cycles and iterations is evaluated in a retrospective approach. The aim of this stage is to incorporate all data and draw a coherent empirical base for the model. This phase is also reporting phase. In this phase, the impact and implications of the developed intervention model to solve the existing educational problems are handled. The data analysis for overall progress and individual progress is presented in the finding. Parts that was also evidence. For the development of the intervention model as the product of the whole study. The possible use of the model in different contexts discussed. Afterwards, the study is reported, and the further implications are discussed. The evaluation process is visualized in Figure 3.12 below.

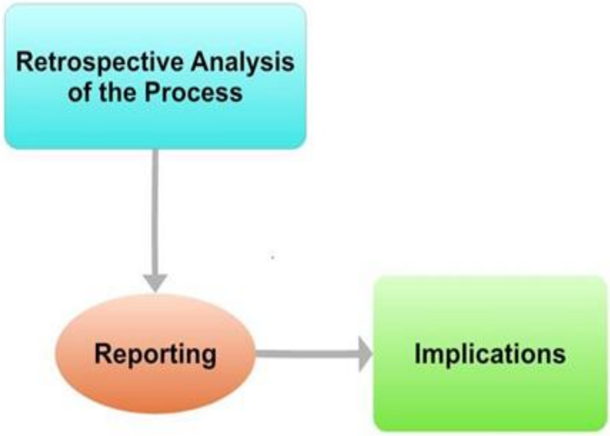

Figure 3.12 Steps of evaluation phase

3.3 Participants and Settings

Six participants (ISToGs) joined to the research voluntarily. These participants are science teachers who have at least seven years of teaching experience. The participants are ISTs of middle school level gifted students (BILSEM) from four cities of Turkey (Istanbul, Izmir, Sanliurfa and Tokat). The universe of the research involves science teachers of elementary level gifted students. The sampling method was done according to convenience sampling method, where the available participants from the universe join the study. Participation was based on volunteerism principle. After the initial phase of the research, one participant left the research. At the beginning of the study, participants were informed about the description of the study, responsibilities, and types of data that is gathered throughout the study, calendar, and ethical issues. Participants were assured that they can leave anytime, the personal information is kept, and data is anonymous. Participants are given with pseudonyms as Hasan, Ebru, Sude, Pelin, Eda, and Cem. Confidentiality is kept.

3.4 Data collection

As mentioned earlier, this design research has mainly three phases and various data continuously collected throughout the progress of the research. In the awareness phase, individual interviews were done with participants and participants' didactic science texts are collected. Each participant designed three science texts, which are also used in real teaching practices. The data collected in the awareness phase is considered as pre-data collected before the interventionist implementations. After the awareness phase, data is collected in each part and iteration of the HLTs. The HLTs involve recognize, overt instruction, participant's text designs in iterations, evaluation interviews for deeply understanding designed texts and the implementation. Data collected in the recognize steps include discussion interviews. Design steps include participant's multimodal text designs, and evaluation steps include interview data.

3.4.1 Data Collection Tools

Data collection tools for interviews are semi-structured open-ended interview questions. The interview questions are prepared by the researchers. Before the actual interviews, interview questions are evaluated by an expert and two pilot interviews were done to test how the questions work and how effectively they reveal the intended data. After expert evaluation and pilot interviews, the interview questions are revised and used. Interview forms used in the research are briefly given below.

3.4.1.1 Interview Forms During the Research

a. **Pilot interviews:** Pilot interviews were conducted with two experienced science teachers who were not participants in order to see and mature the effectiveness of the interview questions originally prepared as drafts.
b. **Awareness Interviews:** At this stage, participants conducted an awareness interview on the effects of scientific texts on meaning learning, their pedagogical practices, semiotic resources, modes, different types of texts and text design.

c. **Recognize Interviews:** These interviews involve questions, when the participants experience various forms and functions of multimodal texts.
d. **Design Interviews:** In order to understand the design and design strategies of the participants, individual interviews were conducted with the participants on the texts they designed.
e. **Evaluation Interviews:** Due to the nature of design-based research, it is necessary to evaluate the application itself and test its effectiveness as the application progresses. Participants were interviewed to evaluate the application and activities.
f. **Final Evaluation Interviews:** Final evaluation meetings were to evaluate the implementation of research in a retrospective approach and the further implications.

The interviews questions were prepared by taking recommendations of an expert. In addition, interview questions were tested and revised by interviewing with two science teachers who did not participated to the research. Second data collection tool involves, as said earlier, participants didactic text designs. These texts are designed in each related step of the research in digital format by use of the various production applications and tools. Data collected from interviews and texts are not used in isolation, they are used in collaboration and triangulation. The supplement each other to see how the situations is now, and how it is developing throughout the design interventions. In the Figure 3.13 below, the data collection timeline is given. The figure summarized which data set was gathered in which part of the study.

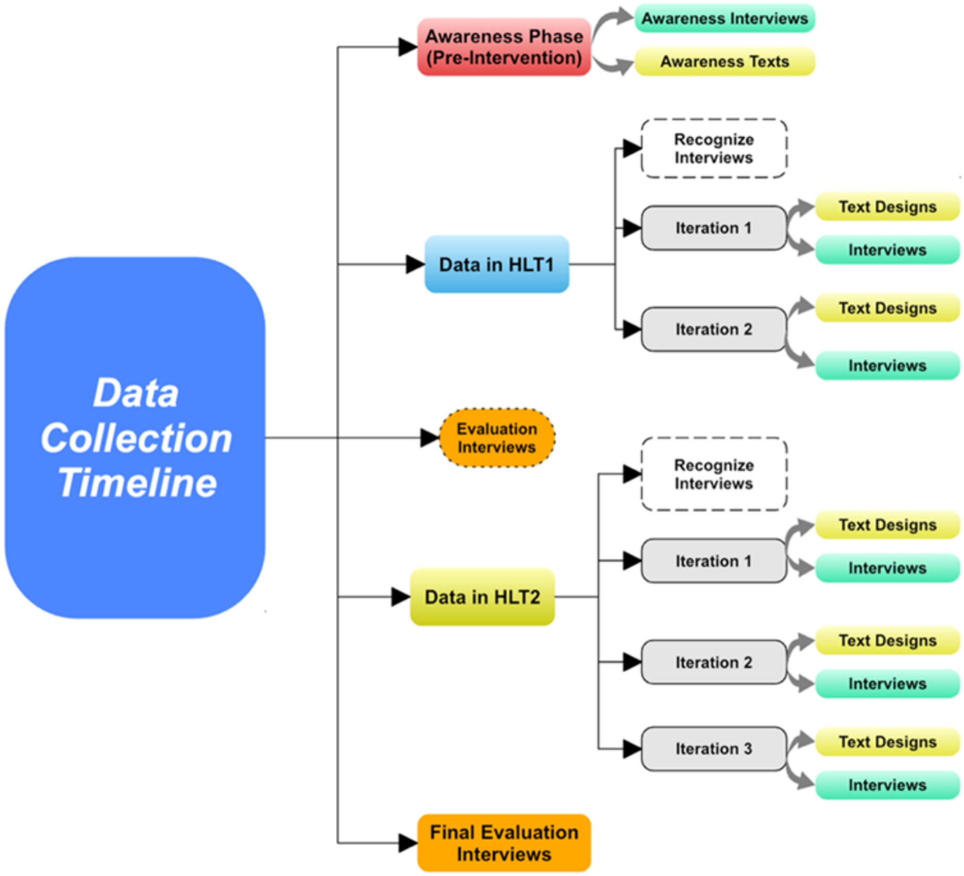

Figure 3.13 Data collection timeline

3.4.2 Trustworthiness

The trustworthiness of data collection tools involves reliability and validity aspects. As said earlier, data includes interviews and participant text designs. Reliability of the text analysis comes from the inter-rater and intra-rater reliability as stated below. What is more, the interview questions were tested through pilot interviews. The validity of the data collection and data analysis comes from various resources. The external validity is ensured since the theory driven aspects of the study, experts' views on developed data analysis framework, experience over time, triangulation of data, and member checking. The internal validity is addresses through the transferability or generalizability of the of the research findings in other contexts or situations. The reliability and validity aspects are visualized in the Figure 3.14 below.

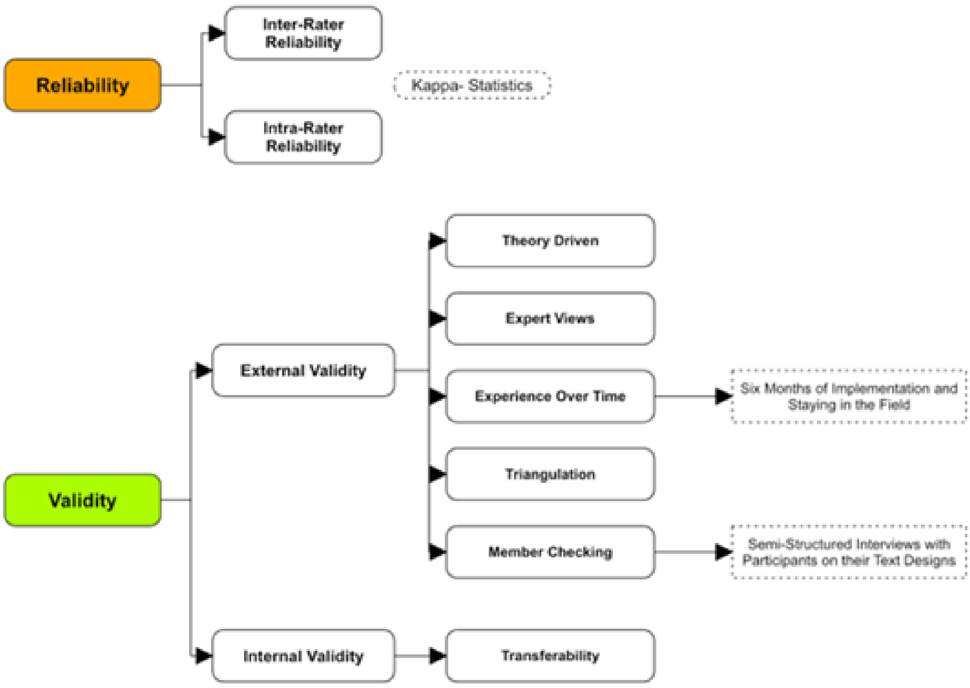

Figure 3.14 The reliability and validity issues

3.5 Data Analysis

Savin-Baden and Major (2013, pp. 46–47) express that a researcher views data through research lenses embraced by the researcher(s). The set of research lenses involve the paradigm, phenomenon, approach, data collection, and data analysis. This study is theory- driven where the paradigm is post-structural theory, phenomenon is MDST design competency, and the approach involves social semiotics and SF-MDA.

3.5.1 Analysis of Interview Data

Interviews result open-ended responses. Data is collected in Turkish. The researcher transcribed data and translated into English. In the translation process expert views were taken. This qualitative data is analyzed through thematic analysis. The data is coded and categorized. We followed the data analysis strategy proposed by Braun and Clarke (2019, p. 50) in Figure 4.16 The data analysis strategy is visualized below.

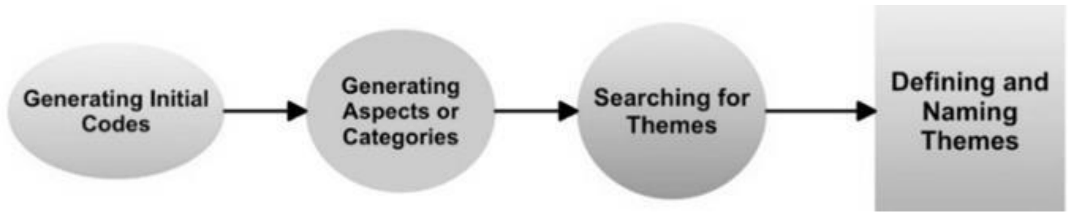

Figure 3.15 Thematic analysis procedure

3.5.2 Observation Protocol for Analysis of MDSTs: Development of STOP

As mentioned in Section 3.2, To analyze the multimodal science texts, the developed data analysis framework, which is based on systemic-functional multimodal discourse analysis (SF-MDA) (O'Halloran, 2007, 2008), is used. Texts are both qualitatively and quantitatively analyzed to demonstrate the current competency levels and developmental trends. In order to more accurate analysis of each text, an observation protocol is developed. This observation protocol is called as semiotic text observation protocol (hereafter STOP) as seen in the Figure 3.16. STOP has two main functions. The first is to make qualitative analysis of texts in a systematic way. The second function is to convert the qualitative data into measurable entities, and therefore, present the data quantitatively. The quantitative presentation of data helps to show the situation and progress in a sound and objective manner.

The STOP has two functional parts. The first part is related to paradigmatic dimension of a text, and second part focuses on the syntagmatic dimension of a text. First part analyzes the ideational meaning system choices in the text. In other words, the first part is used to observe the paradigmatic choices made in the text design. This is done at component level and element level. The first part has four sub-parts. The first sub-part aims to reveal which modes are used to demonstrate the elements.

This helps to reveal how many different modes are used to demonstrate the information in conveyed by the element. The second sub-part aims to figure out which intersemiotic mechanisms are deployed in multimodal representation of elements. The sub-third part aims to show which meaning types are employed to make meaning of the content conveyed by the element. This sub-part is specifically important in revealing of the mixed-mode semiosis of Lemke happened. The last sub-part involves the type of variation made in the element. This included implicit and explicit variation. The second part of the STOP involves the compositional aspects of a text that can be considered as syntagmatic choices in the design of the text. This part mainly focuses on the textual metafunction embedded in the text. Therefore, the second part helps to observe how the ideational and interpersonal metafunction are regulated through the composition of the text. First sub-part of the second part deals with how the text elements are located. Second sub-parts deals with if the critical aspect in the text is foregrounded and peripheral aspects are backgrounded. The third part focuses on how the different meaning units (components, items, or micro-genres) are related to each other. Fourth part is about the headings used in the text. Use of different font sizes and different font colors are attributed composition strategies related to heading. Final sub-part is about relative sizing of the different elements or meaning units in the text.

Text	Components	Elements	Modes			ISM	Meaning Type		Variation	
Items			L	VI	MS		Tip	Top	Imp.	Exp.
Item 1	Component 1	Process								
		Participant								
		Circumstance								
	Component …	Process								
		Participant								
		Circumstance								

	Placement of Text Elements			Foregrounding / Backgrounding		Degree of Framing/Relation			Heading/ Subheading		Relative Sizing
Text	Left/Right	Right /Left	Centering	Critical	Peripheral	Line Zones	Colored Zones	Arrow	Font Size	Font Color	
1											
2											

Figure 3.16 The semiotic text observation protocol (STOP)

3.5.2.1 Analysis of Texts Quantitatively by Use of the STOP

The first analysis unit focus on the mode level or how many different modes are employed to demonstrate content. Components are analyzed as including only one mode, including at most two modes, and including at most three modes. If all transitivity system elements are demonstrated in one mode, the mode level of component is accounted as one-mode component. If one of the three transitivity system elements is represented two modes, the component is accounted as two modes. Similarly, if one of the three transitivity system elements of DRAs is represented three modes, the component is accounted as three modes. For the transitivity system elements, mode levels for each element are also analyzed. In the demonstration of situation and progress, percentages of one-mode, two-mode, and three-mode representations are presented. For the ISMs, number of ISMs are determined. In the demonstration of progress, the number of each intersemiotic mechanism per text is demonstrated. For example, in there are 10 texts in a HLT and number of total semiotic metaphor is 15, the average use of semiotic metaphor as an intersemiotic mechanism is calculates as 15/10 (1.5). This demonstrated the density in the use of intersemiotic mechanism.

Meaning types involve that which meaning types is employed to represent the transitivity system elements. As said earlier, visual imagery demonstrates topological meaning, language mode demonstrates typological meaning, and mathematical mode can demonstrate both meaning types depending on the use. The use of meaning types is directly related to used mode types. For example, if language and visual imagery is used to represent a component or an element both typological and topological meaning are used, so, meaning is contextualized. Use of language mode and mathematical mode together can yield only topological meaning and use of both mathematical mode and visual mode can yield only topological meaning as well. The analysis of use of meaning types how many meaning types are employed to show transitivity system elements. If all elements are demonstrated only with one meaning type, the component is accounted as only typological or only topological. If at least one of the three elements is demonstrated by typological and topological meaning type, the component is accounted as including typological and topological.

As said earlier, the variation term is used to illuminate whether contrasting options or instances of any transitivity system elements are given to make the element more understandable. This part in the STOP looks for the use of implicit variation (no contrasting option or instance is given), and explicit variation (at least one contrasting option or instance is given). If all three elements are given with only implicit variation, the component is accounted as implicitly variated, if at least one of the elements are given with explicit variation; the component is accounted as explicitly variated. For the compositional aspects, analyzed texts are coded as including relevant aspects.

3.5.2.2 Reliability and Validity of the STOP

The STOP is theoretically originated to SFMDA (O'Halloran, 2007, 2008) and VTL (Marton & Tsui, 2004). By dividing the text different strata, it focuses on semantic stratum elements and how three metafunctional meaning are instantiated through paradigmatic and syntagmatic choices. These theoretical underpinnings address the validity issues of the STOP. Furthermore, for the face validity of the data analysis framework and STOP, three experts, who have long time experience in semiotics, multimodality, systemic functional theory, and meaning making, gave approvals.

In accordance with Smith et al. (2013) and West et al. (2013), the STOP was developed in parallel to procedure of Rui and Feldman (2012) to test reliability of the STOP. To test the reliability of the STOP, inter-rater and intra-rater reliability tests were done. The inter-rater reliability text is done by in following procedure. Two texts are randomly chosen and analyzed by the researcher and another researcher who is an expert on the related field and has long-time experiences. For intra-rater reliability, same researcher made observation in two distinct times (2 weeks long time gap). Cohen's Kappa test is used to see consistency between observations. Intra-rater and inter-rater reliability scores are given in tables below.

Table 3.1 Kappa results of intra-rater reliability for paradigmatic choices

	Modes	*Intersemiotic Mechanisms*	*Meaning Type*	*Variation*
Text 1	,878	,713	,832	,712
Text 2	,859	,752	,831	,726

Table 3.2 Kappa results of intra-rater reliability for syntagmatic choices

	Placement of Text Elements	*Foregrounding / Backgrounding*	*Degree of Framing /Relation*	*Heading/ Subheading*	*Relative Sizing*
Text 1	,878	,849	,736	,843	,856
Text 2	,859	,846	,821	,879	,879

Table 3.3 Kappa results of inter-rater reliability for paradigmatic choices

	Modes	*Intersemiotic Mechanisms*	*Meaning Type*	*Variation*
Text 1	,765	,687	,726	,676
Text 2	,789	,743	,765	,721

Table 3.4 Kappa results of inter-rater reliability for syntagmatic choices

	Placement of Text Elements	*Foregrounding / Backgrounding*	*Degree of Framing/ Relation*	*Heading/ Subheading*	*Relative Sizing*
Text 1	,821	,756	,715	,796	775
Text 2	,843	,816	,745	,815	,805

4
FINDINGS

In this descriptive and interventionist design research, the aim is to develop PD-MUST program. Therefore, the development of this program can be understood from the data continuously gathered in different step of the intervention and this data demonstrated how the competency levels of participants on designing MDSTs. In this wise, the findings are presented in a progressive trend where the situation before the intervention, during the intervention, after the intervention is demonstrated. The data gathered in this study comes from open-ended semi-structured interviews and participant text designs. The data gathered in awareness phase (pre-intervention), HLT1, and HLT2 are analyzed and presented separately in two forms. These are the three stages of the research and data collection. The first form is the demonstration of development as a whole group (overall progress), therefore, progress of whole group demonstrated in a cumulative approach. Second form includes the demonstration of individual progress. In this form, participants' texts designed at the end of each step are also provided.

Data is analyzed both quantitatively and qualitatively. Interview data is thematically analyzed and used to support qualitative text analysis. The texts are analyzed both quantitatively and qualitatively. The qualitative data is analyzed with the support of quantitative results. By use of the STOP, all texts gathered in all phases of the research analyzed and findings presented quantitatively as percentages and frequencies of observation. Texts chosen as exemplary cases are qualitatively analyzed and interview data is used to support arguments.

The research question and sub-questions of the research are expressed as below.

How does the professional development program for multimodal didactic science text design with design based and transformative characteristics support multimodal didactic science text design competencies of in-service science teachers of elementary level gifted students?

1. What are the prior MDST text design competency levels of in-service science teachers of elementary level gifted students before the implementation of professional development program for multimodal didactic science text design?
2. What is a teaching-learning strategy that would help in-service science teachers of elementary level gifted students to achieve these goals?
3. How (well) is professional development program for multimodal text design (design) implemented?
4. What are the effects/results of implementing professional development program for multimodal text design (design)?

The findings section includes following parts (data sets).

Whole-Group Findings

a. **Findings of Awareness Phase (Pre-intervention):** Findings for problem definition and awareness
    - Awareness Interviews
    - Quantitative analysis results of texts
b. **Findings of Development (Prototyping) Phase (Whole Group Data):** Overall progress of participants and Development of Intervention Model
    - Findings obtained in the development of HLT1.
        - Recognize step findings.
        - Findings obtained in the first iteration
        - Findings obtained in the second iteration.
        - Findings demonstrating developmental trends for paradigmatic text aspects.
    - Findings obtained in the development of HLT2.
        - Recognize step findings.
        - Findings obtained in the first iteration.
        - Findings obtained in the second iteration.
        - Findings obtained in the third iteration.

- Findings demonstrating developmental trends for syntagmatic text aspects.
- Mid-evaluation interview findings.
- Post-Intervention Interview findings.

c. **Findings of Development (Prototyping) Phase (Individual Progress):**

- Participants' text qualitative text analysis with the support of interview data.
- Demonstration of participants' progress with quantitative data.

Figure 4.1 demonstrates the alignment between the research questions and findings. The aligments point out the research questions and which data set provides answers the relevan research question.

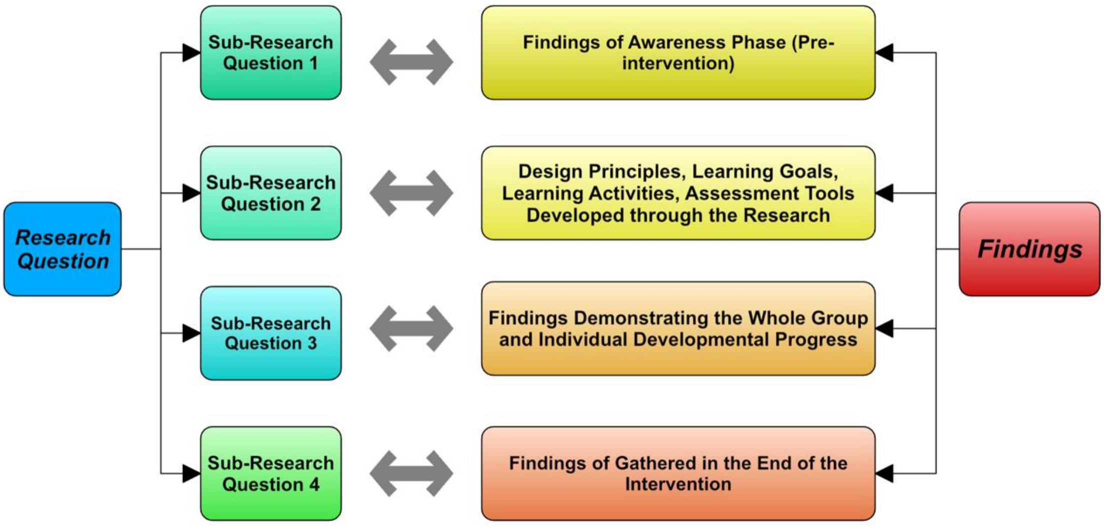

Figure 4.1 The alignment between research questions and findings

4.1 Findings of Phase 1 (Awareness Phase)

4.1.1 Awareness Interviews findings.

In the awareness phase an open-ended interview was done to reveal the views and classroom practices regarding following isues. First, how didactic science texts affect meaning making? Second factors affecting meaning making of science concepts or scientific knowledge are asked. Third, the pedagogical strategies the participants follow before designing didactic science texts are asked. Fourth, views about the nature of communication of scientific knowledge are explored. Finally, the ways in which the semiotic resources used in texts and compositional features of texts can affect meaning making of content and student's learning products are explored. These interviews also provide data for the determination of the problem of the study. Therefore, the interviews are part of both problem definition and determining the awareness of participants. Interview data is analyzed through thematic analysis method and regarding themes are presented below. In the Table 4.1 the themes and observed participant responses with respect to each theme are presented.

Table 4.1 Themes and participant responses figured out awareness interviews

Theme		Hasan	Ebru	Sude	Pelin	Eda	Cem
1	Designing or selecting didactic texts are not a planned pedagogic activity before lessons.	X	X		X		X
2	Participants do not see the design and structure of didactic texts as factors that can affect meaning making of the science concepts.	X	X		X		X
3	While participants use a wide range of modes in their texts, but they have a limited pedagogic strategy when they choose or design the didactic texts.	X	X	X	X	X	X

Table 4.1 Themes and participant responses figured out awareness interviews (cont'd)

4	Meaningful Communication of scientific knowledge is made possible through classroom interactions based on language, but multimodal nature is not expressed.		X	X		X	
5	Participants use a wide range of modes in their texts, but they do not have sufficient explicit knowledge about the meaning making potentials (affordance) of those modes.	X	X	X	X	X	X
6	Participants see text as meaning making resource that has made up of only written language and see scientific text as made up of only written information that are empirically tested and proved.	X	X	X	X		

Designing or selecting didactic texts are not a planned pedagogic activity before lessons.

Data revealed that participant teachers do not consider designing or selecting appropriate didactic texts as a part of their preparations before the lessons. When it was asked, common view was that participants generally choose representations with limited pedagogic strategy. Linguistic representations are dominantly chosen to demonstrate knowledge, but visuals are mostly preferred to attract attentions and concretization of the content. This leads to lower level of contextualization of meaning since appropriate meaning making relation (intersemiotic mechanisms) and modes to represent meaning types cannot be built. For example, one participant expresses that:

Cem: *I focus on selecting interesting and attractive visuals related to content. Afterwards, I put the visuals next to the written language.*

Sude: *When I design or select a text, I focus on attractive, funny, and moving images. The presentation should not be boring or dominant with written language. The most essential parts of my text are attraction.*

Participants do not see the design and structure of didactic texts as factors that can affect meaning making of the science concepts.

Participants generally pointed out that existing knowledge, daily life experiences and misconceptions affect the meaning made. One biggest reason behind the daily life experiences and existing knowledge structure implies the concretization of the content. Although most participants mentioned the importance of concretization, only one participant proposed the importance of concretization through represenations. Some exemplary responses are given below.

Hasan: *The first thing comes to my mind is the pre-existing knowledge and daily life experiences related to the concept or content they are learning. These factors majorly affect the meaning making and learning of the content.*

Ebru: *Since relating the theoretical knowledge with the corresponding daily life experiences or phenomena is quite crucial for learning, their daily life experiences have a privileged position in meaning making of the content.*

Sude: *If the concept is abstract, concretization comes first. I try to embrace strategies that will make the content more concrete and understandable. This can be done, for example, through a hands-on activity, by demonstrating a model etc. Furthermore, giving examples from daily life can be an effective for concretization of the content.*

Cem: *Use of analogies and active participation can be effective ways. Therefore, I try to make these strategies as much as ample during lesson activities.*

During all interviews, there was no response including that the texts and structure as a significant factor that can affect meaning making of the content. Teachers dominantly see existing knowledge structure and active student experiences (e.g., laboratory classes) as main resources of meaning making.

While participants use a wide range of modes in their texts, but they have a limited pedagogic strategy when they choose or design the didactic texts.

Participants dominantly consider that the semiotic resources that make communication of scientific knowledge and meaning making of science content possible are tools that attract attention or increase motivation. Participants see attracting attention on the content in teaching one of the most important factor for meaningful communication. Nevertheless, this is expressed mostly as something teacher must do and not attributed to any feature or characteristics of the texts itself. It was observed that although participants use variety of modes, they mostly see language as sole means of communication of scientific knowledge. It was observed that there is strong stereotype of 5E model of constructivist approach since almost all teaching and learning activity examples are given according to this model. Accordingly, main role of representations is seen in the engagement part of this model that is about engaging student into the lesson activities.

Hasan*: In my texts or presentations, I generally use a photo or visual that can attract the attentions. This can be a good strategy to increase motivation at the beginning. Afterwards, I use different kinds of resources such as video, pictures, animations etc. The main feature of my representations is the attraction.*

Cem: *Firstly, the presentation must attract students' attention. Therefore, I try to use a wide range variety of resources to attract the attentions.*

Nonetheless, one participant expresses that, the first thing she consider when she designs the didactic texts is learning goals. Afterwards, she chooses the representations that meet the learning goals. However, there was not any idea about the characteristics of representations or texts that meet the learning goals.

Ebru: *The first thing I concern is whether the representations meet learning goals. After I determine the learning goals, I choose various representations such as photos or visuals that convey the meaning pointed out by the learning goals.*

Some participants express the situations where language have low potential to demonstrate intended meaning. They see visuals as an 'alternative' and better resource for meaning making. Furthermore, mathematical formulas were not expressed as a semiotic resources system that can make meaning itself or as a separate mode. Language and visual imagery are seen as alternatives to each other and use and integration of them in didactic texts does not seem to involve a conscious and planned multimodal text design in a pedagogic strategy.

Meaningful Communication of scientific knowledge is made possible through classroom interactions based on language, but multimodal nature is not expressed.

Common view is that participants give language a privileged position in communication of scientific knowledge. It was observed that the collaboration and integration of diverse modes in demonstrating the meaning of concepts or scientific knowledge were not explicitly expressed. For example, one participant expresses this aspect in below.

Pelin: *Language is the sole means of communication. Other resources play a complementary role in the communication.*

Some participants express that use of various materials in classroom may enhance meaning making since the students in the class have diverse types of intelligence.

Cem: *Resources other than language may play a crucial role. The communication should help student use various perception systems such as seeing, hearing. Therefore, using a picture, an animation, or laboratory class activities may address different types of intelligence.*

Participants use a wide range of modes in their texts, but they do not have sufficient explicit knowledge about the meaning making potentials (affordance) of those modes.

Participants attribute importance to the texts used in the classes, but the have quite limited knowledge on the characteristics and features of science texts that enhance meaning making of science concepts in gifted science classroom. Attracting attention to the content or subject is seen as main factor for learning. It was observed that participants have limited explicit knowledge about the affordances of semiotic resources and modes that make communication of scientific knowledge possible. During the interviews, role of mathematical mode of scientific knowledge in meaning making was not mentioned. Furthermore, visual imagery mode is seen as a complementary resource to language. Although participants expressed the value of non-linguistic modes, main actor in meaning making of science content and student conception is majorly language mode.

Sude: *I choose visual images, which are aesthetics and decorative accompanying to language. These images also contain the content.*

Participants see text as meaning making resource that has made up of only written language and see scientific text as made up of only written information that are empirically tested and proved.

When the question "what is a text?" explicitly asked, participants overwhelmingly answered as in following. *Texts are piece of information that is expressed through linguistic mode*. Participants majorly delineated texts as a meaning making tool including linguistic mode and other modes were not explicitly explicated as parts of something that could be seen as a text. When further explanations are made about other modes that may be included in science texts, participants generally realize accept the multimodal nature of science texts.

Hasan: *I consider a text as made of written language and scientific text can be seen as a piece of scientific knowledge expressed in written language.*

Ebru: *I think that text refers to visual form of written language.*

Sude: *A plain form of written language come to my mind when I think a text. Scientific texts contain references and citations, and visuals and graphics can be included.*

*Eda: A text is made of linguistic elements. What can be else? (*Astonished*). Whey you say a text, I imagine a piece of information expressed in written language. I do not image visual imagery or diagram.*

It was observed that, participants generally have misconceptions about the description of a text. They expressed contradictory statements about the definition and included semiotic resources and modes of a text. Furthermore, when a science text is showed participants, they had difficulties in determining the meaning units and different parts of a science text when they analyze. Diverse responses given to the structural aspects and meaning units in the texts. This demonstrated that participants have limited explicit knowledge of compositional aspects (syntagmatic dimension) of didactic science texts, which can enhance meaning making. One possible reason is that they have not consider the texts in this perspective. Some participants expressed that they have not considered the text in suc a respect.

These interviews yielded the following implications. First, participants do not consider the science texts as a significant factor that can affect meaning making and understanding of the scientific knowledge and conceptualization. Second, participants majorly do not have a pedagogic strategy in choosing and designing the didactic texts. Third, although they use wide variety of semiotic resources and modes in their texts, they have limited knowledge of affordances of different modes, integration of modes to enhance meaning making, and the compositional aspects of texts that can make understanding the content easier and help to produce meaningful learning products. Fourth, participants are overwhelmingly considered that active student participation is something student actively do or produce something, but this study considers that students can be active when they internalize a concept or phenomenon, therefore, interacting with a well-designed learning resource can help students be active as they internalize the content. Fifth, use of different modes can help students address needs of a wide variety of different types of intelligence in a gifted science classroom since use of various modes stand for various types of perceptual systems. Since science text is one of the most significant part of communication of scientific knowledge, meaning making of content, and creative learning products in gifted science classroom and since communication of scientific knowledge have a multimodal nature, teachers need to have explicit knowledge of designing multimodal didactic texts. The interview data revealed that teachers have limited knowledge and strategy in designing these texts.

Cross-Case Analysis of Awareness Interviews

Regarding the firs question, participants responded various answers. While Hasan, Sude, and Eda responded that existing knowledge and previous experiences are the factors that may influence meaning making of the content, Ebru, Pelin, and Cem responded that the concretization of the content is the main factor for meaning making. Regarding the features of an effective representation, Hasan and Cem responded that the representation must attract the attention. Nonetheless, Ebru and Eda proposed that, an effective representation should include engagement questions. While participants generally responded that the main mediating tools is the language in the communication of scientific knowledge, the secondary mediating tools are differently proposed. For example, Hasan, Pelin, and Eda expressed that experiments and experiment tools have the prominent place in the communication of scientific knowledge while Ebru, Sude, and Cem have given priority to visuals and presentations.

All participants responded that, a text involves only language mode. But, when further clues are given, Ebru, Sude and Cem changed their responses. Ebru stated that a text may involve semiotic resources other than language such as visuals. Cem proposed that visuals and written language complements each other to produce meaning in the text. Furthermore, participants diversely responded the question involving meaning of a science text. In this respect, Ebru and Eda responded that, a science text involves results of experiments while Sude responded that a science text may involve definition of concepts or scientific processes. Regarding the strategies in choosing or designing didactic science texts before and instruction, all participants firstly responded that the first thing is that the texts need to be attractive. Sude added that "I focus on text to be succinct and as short as possible". Ebru expressed a response which was not given by other participants. The response was that "*I give attention on the appropriateness for cognitive level and age when I choose or design a text*". Pelin's answer was the only answer regarding the content. She stated that the text needs to be comprehensive in terms of giving information. In sum, participants expressed somewhat similar and limited answers with respect to the functions, features, and impacts of didactic texts used in gifted science classroom.

4.1.2 Analysis of Texts Gathered in the Awareness Phase

4.1.2.1 Paradigmatic Dimensions of the Texts

As said earlier, didactic science texts are explored and analyzed regarding the paradigmatic (modes and semiotic resources) and syntagmatic (text composition) dimensions. In this respect, texts are analyzed qualitatively and by the use of STOP. The In the awareness phase totally 18 texts are analyzed. Each participant provided texts that they use their actual teaching practices. There were observed totally 127 components and 381 elements. The average number of components per text is seven. The analysis results are given in tables and figures below.

Table 4.2 Frequencies of components and elements regarding mode level

Participant	Mono-Mode				Dual-Mode				Triple-Mode				Total Components
	Pro	Par	Circ	**C**	Pro	Par	Circ	**C**	Pro	Par	Circ	**C**	
Hasan	26	22	25	**24**	6	10	7	**8**	0	0	0	**0**	32
Ebru	17	17	17	**17**	3	3	3	**3**	0	0	0	**0**	20
Sude	14	15	16	**12**	3	2	1	**5**	0	0	0	**0**	17
Pelin	8	8	8	**8**	0	0	0	**0**	0	0	0	**0**	8
Eda	8	9	8	**8**	2	1	2	**2**	0	0	0	**0**	10
Cem	31	24	27	**24**	9	14	10	**14**	0	2	3	**2**	40
Total	104	95	101	**93**	23	30	23	**32**	0	2	3	**2**	127
%				**73**				**25**				**2**	

*Pro: Process, Par: Participants, Circ: Circumstance, C: Component

Table 4.2 demonstrates the number of mono-mode components is 93, dual-mode is 32 and triple-mode is two. Pelin's text were made of completely mono-mode (language mode). Participants are mostly observed elements that are represented with two modes and processes are sees least. Figure 4.2 below demonstrates that, 73 percent of components are represented as mono-mode, 25 percent of them are dual-mode, and 2 percent are represented with three-mode. The mode level is dominantly monomodal. 27 % of total components included more than one mode.

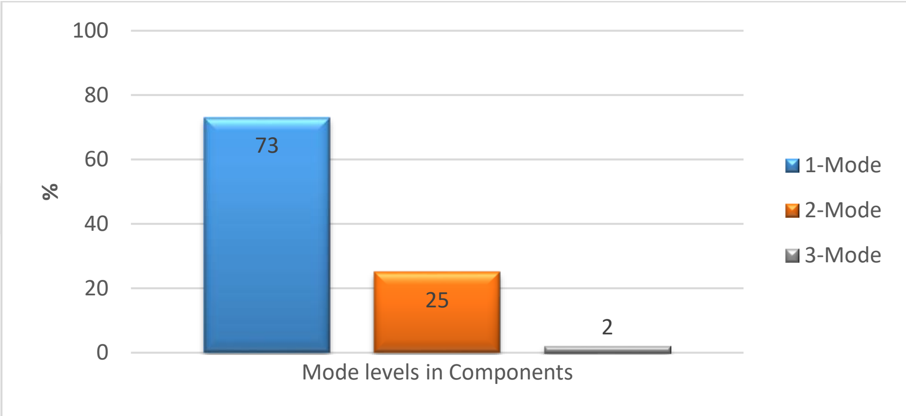

Figure 4.2 Mode levels in the texts designed in the awareness phase

Table 4.3 demonstrates the number of components and elements in terms of meaning types represented by the semiotic resources used. Results demonstrate that 97 of 127 components are represented with only typological meaning types, four of components are demonstrated only topological meaning type, and the number of components that are demonstrated with typological and topological meaning is 28. Figure 4.3 below demonstrates that 76 % of total components are demonstrated with only typological meaning and 20 % of total components are demonstrated with topological and typological meaning. This means that 80 percent of knowledge in the texts is not contextualized using affordance of different modes.

Table 4.3 Frequencies of meaning types in components and elements

Participant	Only Typological Meaning				Only Topological Meaning				Typological and Topological M.				Total Component
	Pro	Par	Circ	C.	Pro	Par	Circ	C.	Pro	Par	Circ	C.	
Hasan	26	24	24	28	0	0	0	0	0	0	2	4	32
Ebru	12	12	12	13	3	3	3	3	3	3	3	4	20
Sude	13	14	16	11	1	1	1	1	3	2	0	5	17
Pelin	6	6	6	8	0	0	0	0	0	0	0	0	8
Eda	16	18	16	8	0	0	0	0	4	2	2	2	10
Cem	31	25	28	27	0	1	0	0	4	11	7	13	40
Total	104	99	102	97	4	4	4	4	14	18	16	28	127
%	85	80	83	76	3	3	3	4	11	15	13	20	

*Pro: Process, Par: Participants, Circ: Circumstance, C: Component

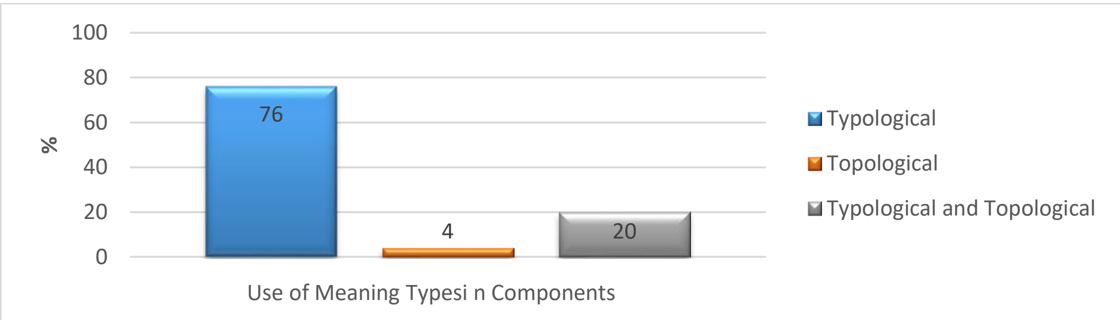

Figure 4.3 Use of meaning types in the texts designed in the awareness phase

Table 4.4 demonstrates the frequency of total ISM types. Totally 70 ISMs observed for 381 elements. The mostly observed ISM is intersemiotic complementarity. The number of observed semiotic mixing mechanism is 16, 9 for semiotic transition and 18 for semiotic metaphor. Semiotic adaption mechanism was not observed. Figure

5.3 demonstrates the average number of intersemiotic mechanisms built for per text. The average number for intersemiotic complementarity is 1.5 per text, 0,9 for semiotic mixing per text, 0,5 for semiotic transition per text, and 1 for semiotic metaphor per text.

Table 4.4 Frequencies of ISMs in the texts designed in the awareness phase

Participant	Text	Elements	IC	SA	SX	ST	SM	Total
All	1, 2, 3	Processes	5	-	5	3	10	23
		Participants	18	-	5	3	3	29
		Circumstance	4	-	6	3	5	18
		Total	27	-	16	9	18	70

*IC: Intersemiotic Complementarity, SA: Semiotic Adaption, SX: Semiotic Mixing, ST: Semiotic Transition, SM: Semiotic Metaphor

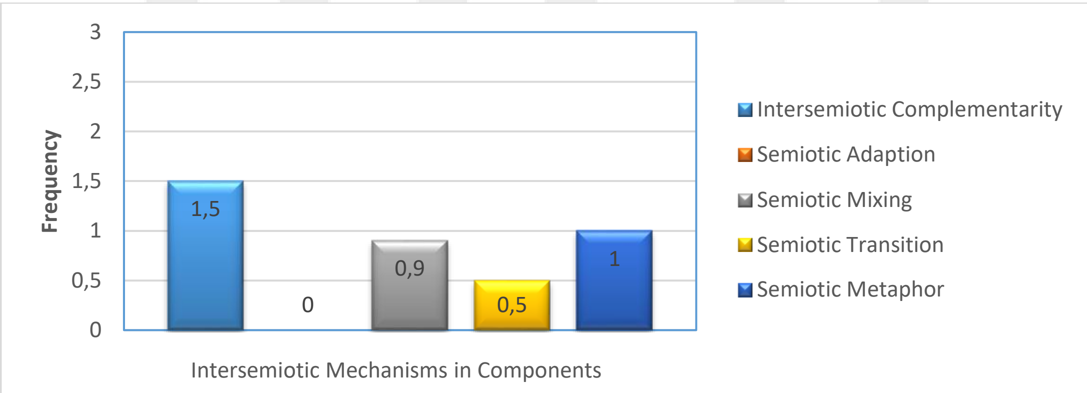

Figure 4.4 Frequency of ISMs per texts designed in the awareness phase

Table 4.5 demonstrates the frequency of implicit and explicit variation observed in the components and elements. For the total processes, 120 elements out of 127 elements are implicitly variated, for participants the frequency for implicit variation is 117 out of 127, and for circumstance elements the situation is same with participants. Figure 4.5 demonstrates that 93 percent of total components are implicitly variated while 7 percent explicitly variated.

Table 4.5 Frequencies of variation types in the texts designed in the awareness phase

Participant	Text	Elements	Implicit	Explicit	Total
All	1, 2, 3	Processes	120	7	127
		Participants	117	10	127
		Circumstance	117	10	127
		Total	354	27	381
		%	93	7	

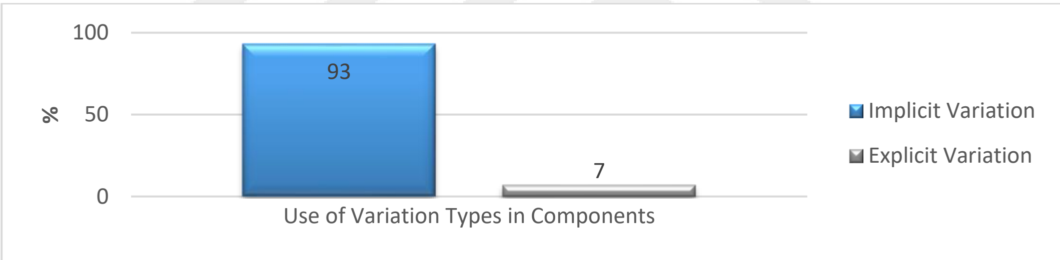

Figure 4.5 Percentages of variation types in the texts designed in the awareness phase

4.1.2.2 Syntagmatic Dimension of Texts (Compositional Aspects)

Table 4.6 demonstrates the compositional aspects of all texts gathered in the awareness phase. When the placement of text elements analyzed, it was observed that 12 of 18 (67 %) text are left/right oriented, 4 of them (22 %) right /left oriented, and 2 of them (2 %) are center oriented. It was seen that 3 of 18 texts (17 %) foregrounded the critical aspects and information of the content and backgrounded peripheral aspects. For relating and separating the text elements, the degree of framing in the texts are observed as in following. 5 of 18 texts (28 %) used line zones and colored zones separately. No text was observed to include arrows for separating and relating text elements. For the relative sizing of text elements, it was observed that in half of the texts (50 %) at least one element had different size in a comparison to other elements in the text. Therefore, the most common compositional feature is relative sizing. However, relative sizing is meaningful when it is done according to criticalness hierarchy and demonstration the criticalness hierarchy seems low since placement of text elements and foregrounding and backgrounding strategies are the main monitors of demonstration of criticalness hierarchy of the pieces of information included in the text.

Table 4.6 Compositional aspects of text gathered in the awareness phase

	Placement of Text Elements			**Foregrounding / Backgrounding**		**Degree of Framing/ Relation**			**Heading/ Subheading**		**Relative Size**
Phase	L/R	R/L	Centering	Critical/ Peripheral	Not Observed	Line Zones	Colored Zones	Arrow	Font Size	Font Color	Observed
Frequency	12	4	2	3	15	5	5	0	17	14	9
%	67	22	1	17	85	28	28	0	95	78	50

4.2 Findings in the Intervention/Prototyping Phase (Phase 2)

This phase involves development of the intervention model within interventionis design experiments. As stated earlier, this phase consists of two HLTs. The first HLT and the second HLT have the steps of recognize, overt instruction, design, feedback and re-design. While HLT1 focuses on paradigmatic dimensions, the HLT2 focuses on syntagmatic dimensions of the MDSTs. The first HLT has been developed in 2 iterations and the second HLT has 3 iterations. Data is gathered in recognize parts and designs steps of each iteration.

4.2.1 Findings of the Development of HLT1

This part includes the finding gathered in the recognize step and iterations of the development phase of HLT1.

4.2.1.1 Recognize Phase of HLT1

In the recognize part of HLT1, as said earlier, four different mode level texts of same content presented to participants and open-ended discussion questions are asked (see Appendix B). The given responses to the discussion questions in recognize parts of HLT1 are analyzed through thematic analysis. After the thematic analysis, we created the aspects and themes (see Table 4.7) regarding how paradigmatic choices in a MDST may affect meaning making of content due to following reasons.

Table 4.7 Aspects and themes derived in the recognize step of HLT1

	Themes			
	1	**2**	**3**	**4**
Aspects	Mode level can be a determinant factor in realizing meaning types and meaning relationship types between entities and concepts in the content.	Increase in the mode level may lead to concretization of the content and reduce abstractness	Mode level may be conceived as a contributing factor to scaffolding effect of the text.	Mode level can lead a semiotic economy in understanding of the content.
a	Mode level can be a determinant factor in realizing meaning types and meaning relationship types between entities and concepts in the content.	Realistic depictions of the entities and symbolization of the concepts.	Connections of different units of the text and relating them.	Time saving. One picture can express many things than many words can do.

Table 4.7 Aspects and themes derived in the recognize step of HLT1 (cont'd)

b	**Helps to recognize the meaning relationships which are mathematical and spatial between the entities and concepts in the text.**	**Depiction of processes within the spatial relations.**	**Use of arrows.**	**Synoptic representation of concepts by symbols and mathematical formulas**

1. **Mode level can be a determinant factor in realizing meaning types and meaning relationship types between entities and concepts in the content.**

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

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

   This aspect is based on the recognition and discernment of the entities and concepts taking part in the content. As the mode level increases, there have seen no difference in the recognition and discernment of the number of entities (typographic meaning). However, there observed some differences in the topological meaning of the entities as the participants pass to next texts. For example, Eda stated that.

Text 1: *...I see an inclined plane, a hill, a car, and traffic lamb... Text 3: ...I see an inclined plane, a car moving down on the hill, starting and points of the movement on the hill, the place where the car cease its move, and traffic lamb...*

However, there observed more differences as the in the numbers of different concepts (typological meaning). Although all texts have same entities and concepts, participants responded a greater number of different concepts when the text changes. The change was mainly typological that participants added very new concept or added a sub-category of a concept they had already recognized. To illustrate this aspect, we present the responses of Sude below,

Text 1: The concepts are kinetic energy, mechanic energy, conservation of energy, total energy, friction force, and work. Text 3: The concepts are ... (added concepts) work, decelerating, height, initial velocity, final velocity, and resting. Text 4: The concepts are ... (added concepts) resting, distance, direction, negative direction.

We see that as the mode level increased discernment of new acpects and sub-aspects in the knowledge and concepts are expressed.

b. Mode level helps to recognize the experiential meaning relationships between the entities and concepts in the text.

Participants responded that as the mathematical modes (formulas) added they easily recognized the quantitative relations became more easily discernible. We saw responses regarding quantitative relations especially when we presented second text that is reconstructed with written language and mathematic mode. To make it clear we present some participant responses to second text.

Ebru: *...the use of symbols and formulas helps me to see mathematical relation between concepts. Now, it is easier to infer that the total energies at initial position and final positions equal.*

Eda: *The inclusion of mathematical formulas instead of fully written language, is better idea since the calculations of energy transformation are simpler now...*

2. **Increase in the mode level may lead to concretization of the content and reduce abstractness.**

The data reveals that use of images or figurative elements (symbols, icons, arrows etc.) helps to concretize entities, concepts, or processes. Participants generally stated that, icons and symbols of concept may envisage various aspects of that concept, an image of an entity can demonstrate qualitative characteristics, or arrows may represent direction of a movement.

a. **Realistic depictions of the entities and symbolization of the concepts.**

This aspect is more related to image mode in the texts. The data reveals that use of images or figurative elements (symbols, icons, arrows etc.) helps to concretize the concepts or entities. An iconic model of concept may envisage various aspects of that concept, an image of an entity can demonstrate qualitative characteristics. Some of responses related to this aspect are represented as in following.

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

b. **Depiction of processes within the spatial relations.**

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

Hasan: *...arrows in this text (text 3) demonstrate the velocity and magnitude of the velocity as the car decelerates... Eda: The third text presents realistic images that depict the process. The image helps me to understand the movement of the car (process) better. Eda: ...the image makes it easier to figure out the initial and final states of the moving car...*

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

3. **Mode level may be conceived as a contributing factor to scaffolding effect of the text.**

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

a. **Connections of different units of the text and relating them.**

Texts has different units those convey pieces of information and meaning. Participants often expressed that the use of various modes make it easier to relate different parts of the content. Those parts may include explanations, calculations, depictions, or questions.

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

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

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

b. Use of arrows and lines

This aspect deals with the use of arrows and lines in texts. As mentioned earlier, one view on the use of arrows was attributed to demonstrate movements inside the text and second was relation of different units of text specified in the aspect 3A. Besides, those aspects, participants expressed that arrows in multimodal texts may help readers to notice a specific aspect or representation. This means that arrows may direct the reader' attention onto a specific field in the content. These comments and responses were seen especially with the Text 4. In this text, some arrows were employed to take readers attention to formula of conservation of energy. By doing this, readers may focus on the summarizing point of the text. Some of the responses related to this aspect is given below.

Eda: *This text (text 4) directs me to focus on the formula of conservation of energy and relate this to other parts… Eda: This text (text 4) is more dynamic. It is most likely to be understood without any assistance from a teacher…*

Teachers also commented on the text structures overall. They mainly responded long when text four is demonstrated. The text structure said to be well-designed with various modes that helps to readers where they need to focus on.

4. **Mode level can lead a semiotic economy in understanding of the content.**

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

a. **Use of various modes can be time saving for readers.**

This aspect engages to time spent for understanding the content depicted by the text. Participants generally stated that use of images and symbols prevents reading many sentences and words and therefore text becomes time saving. The typical argument is that "one picture can stand for may words". Below we present some participant responses related to this point.

Eda: *In this text (text 3) without need for long sentences, the process is depicted using image… Inclusion of image to text accelerates meaning making. …It shortens the time to understand the content. Cem: Use of image in this text (text 3) makes the text more meaningful since the image can represent meanings that many words cannot do…*

b. **Synoptic representation of concepts by symbols and mathematical formulas.**

Another aspect that leads to semiotic economy in multimodal texts is the use of symbols and formulas. This situation leads to economical use of semiotic resources in the text. Below we present some of participant responses regarding this aspect.

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

In the evaluation part, participants were asked that which text they would choose if they were to teach this content. Five participants favored text 4 and only one participant (Ebru) choose text 2. Interestingly, this participant previously stated that "following the process and actions taking place in the content is easier with the text 4". Some of the comments are in below.

Ebru: *I choose text 2 since the use of different resources may lead distractions. Written language mode and mathematical mode seem sufficient… Eda: Text 4 is more organized and easier to focus on and relate the different pieces of information of the text. It is the most attractive and the most convenient to depict flow of the process… Sude: Text 4 concretize the concepts and processes taking place in the content. Therefore, for students it is easier to understand the content with this text.*

4.2.1.2 Findings Gathered in the Design Step of First Iteration of of HLT1

In the design step of first iteration of HLT1, totally 8 texts are designed by participants. There were observed totally 80 components and 240 elements. The data analysis and results are given in tables and charts below.

Table 4.8 demonstrates the number of mono-mode components is 28, dual-mode is 43 and triple-mode is 9. Participants are mostly observed elements that are represented with two modes and processes are sees least. Figure 4.6 below demonstrates that, 35 percent of components are represented as mono-mode, 53 percent of them are dual-mode, and 12 percent are represented with triple-mode.

Table 4.8 Frequencies of components and elements regarding mode level in first iteration of HLT1

Participant		1-Mode				2-Mode				3-Mode				Total Components
		Pro	Par	Circ	C.	Pro	Par	Circ	C.	Pro	Par	Circ	C.	

Table 4.8 Frequencies of components and elements regarding mode level in first iteration of HLT1 (cont'd)

Hasan	*T1*	8	8	8	8	2	2	2	2	3	3	3	3	13
	T2	3	2	3	3	5	6	6	6	3	3	2	2	11
Ebru	*T1*	3	2	3	2	2	4	2	2	1	0	1	2	6
	T2	6	2	6	2	2	6	2	6	0	0	0	0	8
Sude	*T1*	3	2	2	2	3	3	3	3	0	1	0	1	6
Eda	*T1*	13	2	12	4	0	9	1	8	0	1	0	1	13
	T2	9	9	9	4	3	3	3	8	0	0	0	0	12
Cem	*T1*	3	3	3	3	8	8	8	8	0	0	0	0	11
Total		48	30	46	28	25	41	27	43	7	8	6	9	80
%					*35*				*53*				*12*	

*Pro: Process, Par: Participants, Circ: Circumstance, C: Component

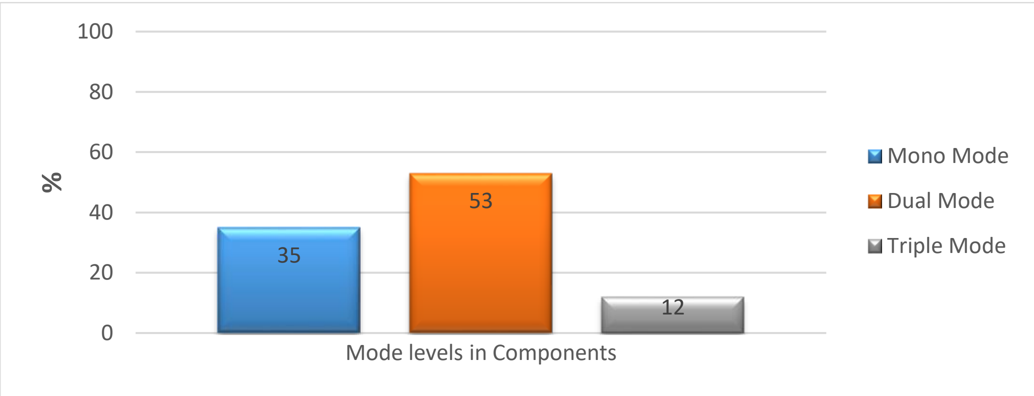

Figure 4.6 Modality levels in the texts designed in the HLT1

Table 4.9 below demonstrates the number of components and elements in terms of meaning types represented by the semiotic resources used. Results demonstrate that 37 of 80 components are represented with only typological meaning types, 1 of

80 components are demonstrated only topological meaning type, and the number of components that are demonstrated with typological and topological meaning is 42. Figure 4.7 shows that 46 % of total components are demonstrated with only typological meaning and 52 % of total components are demonstrated with topological and typological meaning. This means that 48 percent of knowledge in the texts is not contextualized.

Table 4.9 Frequencies of meaning types in components and elements in the first iteration of HLT1

Participant All		Typological Meaning				Topological Meaning				Typological and Topological M.				Total Component
		Pro	Par	Circ	C.	Pro	Par	Circ	C.	Pro	Par	Circ	C.	
Hasan	*T1*	9	9	9	9	0	0	0	0	4	4	4	4	13
	T2	5	5	5	4	0	0	0	0	6	6	6	7	11
Ebru	*T1*	4	4	3	3	0	0	0	0	2	2	3	3	6
	T2	2	2	2	3	5	2	5	0	1	4	1	5	8
Sude	*T1*	2	2	2	2	0	0	0	0	4	4	4	4	6
Eda	*T1*	7	5	7	5	6	0	4	0	0	8	2	8	13
	T2	0	0	0	5	1	1	1	1	4	4	4	6	12
Cem	*T1*	7	7	6	6	0	0	0	0	4	4	5	5	11
Total		36	34	34	37	12	3	10	1	25	36	29	42	80
%					*46*				*2*				*52*	

*Pro: Process, Par: Participants, Circ: Circumstance, C: Component

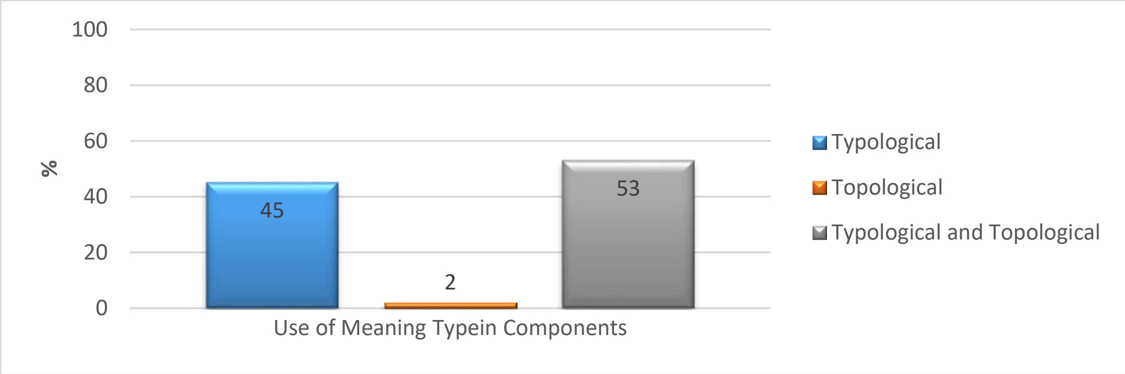

Figure 4.7 Use of meaning types in the texts designed in HLT 1

Table 4.10 below demonstrates the frequency of total ISM types. Totally 103 intersemiotic mechanisms observed for 240 elements. The mostly observed ISM is intersemiotic complementarity. The number of observed semiotic adaption ISM is zero, semiotic mixing mechanism is 4, 41 for semiotic transition and 16 for semiotic metaphor. Figure 4.8 monitors the average number of intersemiotic mechanisms built for per text. The average number for intersemiotic complementarity is 5,25 per text, zero for semiotic adaption, 0,5 for semiotic mixing per text, 5,2 for semiotic transition per text, and 2 for semiotic metaphor per text.

Table 4.10 Frequencies of ISMs in the texts designed in the first iteration of HLT1

Participant	Text	Elements	IC	SA	SX	ST	SM	Total
All	1, 2, 3	Processes	0	0	1	17	6	24
		Participants	27	0	2	12	6	47
		Circumstance	15	0	1	12	4	32
		Total	42	0	4	41	16	103
		Average Per-	*5,25*	*0*	*0,5*	*5,12*	*2*	*12,8*

*IC: Intersemiotic Complementarity, SA: Semiotic Adaption, SX: Semiotic Mixing, ST: Semiotic Transition, SM: Semiotic Metaphor

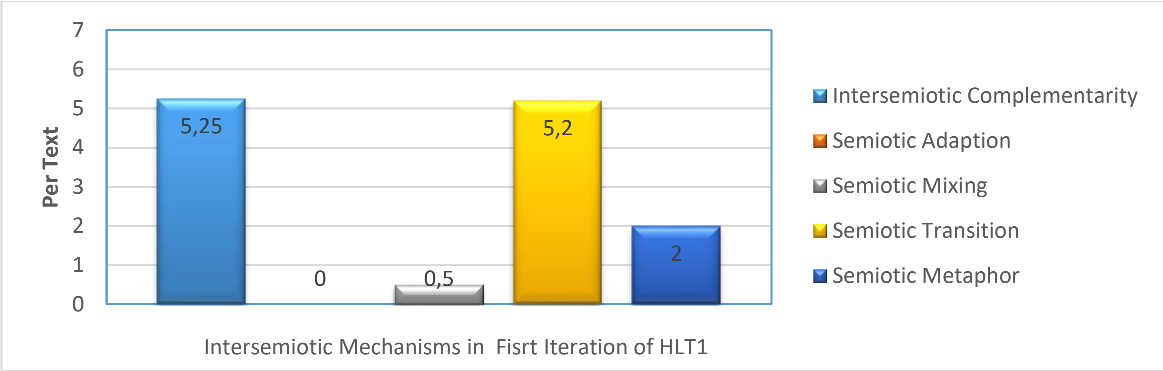

Figure 4.8 Frequency of ISMs per texts designed in the first iteration of HLT1

4.2.1.3 Findings of Second Iteration of of HLT1

In this part, data gathered in the second iteration of development of HLT1. In this part, participants designed totally 8 texts in this iteration.

Table 4.11 Frequencies of components and elements regarding mode level in the second iteration of HLT1

Participant		1-Mode				2-Mode				3-Mode				Total Compo-nents
		Pro	Par	Circ	C.	Pro	Par	Circ	C.	Pro	Par	Circ	C.	
Hasan	*T1*	4	5	4	3	3	6	5	4	5	1	3	5	12
	T2	17	4	4	4	0	13	13	13	0	0	0	0	17
Ebru	*T1*	5	2	4	2	10	13	11	13	0	0	0	0	15
Sude	*T1*	4	1	1	1	4	7	7	7	0	0	0	0	8
	T2	5	1	5	0	2	6	2	7	0	0	0	0	7
Eda	*T1*	1	1	1	1	4	4	4	4	0	0	0	0	5
Cem	*T1*	1	1	1	1	3	3	3	3	0	0	0	0	4

Table 4.11 Frequencies of components and elements regarding mode level in the second iteration of HLT1 (cont'd)

	T2	12	5	4	2	1	7	9	10	0	1	0	1	13
Total		49	20	24	14	27	59	54	61	5	2	3	6	81
%					*17*				*75*				*8*	

*Pro: Process, Par: Participants, Circ: Circumstance, C: Component

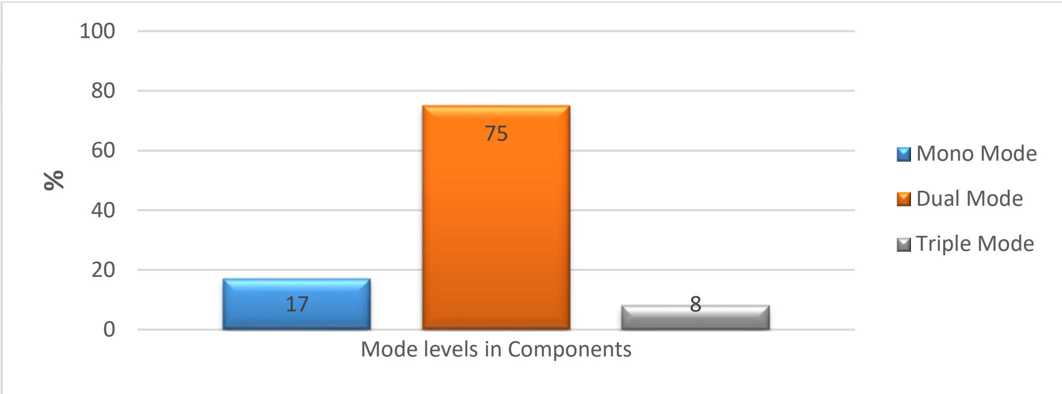

Figure 4.9 Modality levels in the texts designed in the second iteration of HLT1

Table 4.11 demonstrates the number of mono mode components is 14, dual-mode is 61 and triple-mode is 6. Participants are mostly observed elements that are represented with two modes and processes are sees least. Figure 4.9 demonstrates that, 17 percent of components are represented as mono-mode, 75 percent of them are dual-mode, and 8 percent are represented with triple-mode.

Table 4.12 below demonstrates the number of components and elements in terms of meaning types represented by the semiotic resources used. Results demonstrate that 14 of 81 components are represented with only typological meaning types, seven of 6 components are demonstrated only topological meaning type, and the number of components that are demonstrated with typological and topological meaning is 61. Figure 4.10 shows that 22 % of total components are demonstrated with only typological meaning and 75 % of total components are demonstrated with topological and typological meaning. This means that 25 percent of knowledge in the texts is not contextualized. This finding demonstrates that there is an increase in the use of contextualized components in the texts in the second iteration.

Table 4.12 Frequencies of meaning types in components and elements in the second iteration of HLT1

Participant		Typological Meaning				Topological Meaning				Typological and Topological M.				Total Component
		Pro	Par	Circ	C.	Pro	Par	Circ	C.	Pro	Par	Circ	C.	
Hasan	*T1*	6	5	6	5	0	0	0	0	6	7	6	7	12
	T2	10	0	0	2	4	4	4	4	3	13	13	11	17
Ebru	*T1*	5	1	2	2	1	1	1	0	9	13	12	13	15
Sude	*T1*	0	0	0	0	3	1	1	1	5	7	7	7	8
	T2	6	1	5	0	0	0	0	0	1	6	2	7	7
Eda	*T1*	10	9	9	3	0	0	1	0	2	3	2	2	5
Cem	*T1*	0	0	0	0	1	1	1	1	3	3	3	3	4
	T2	11	5	3	2	2	0	1	0	0	8	9	11	13
Total		48	21	25	14	11	7	9	6	29	60	53	61	81
%					*18*				*7*				*75*	

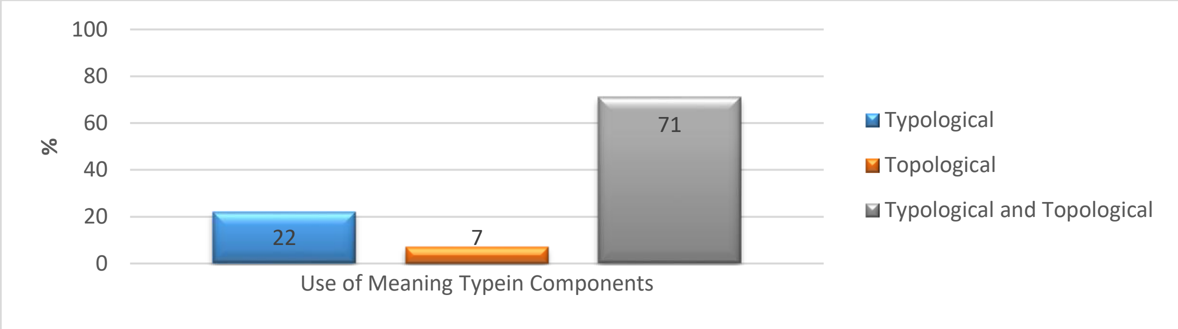

Figure 4.10 Use of meaning types in the texts designed in second iteration of HLT1

Table 4.13 demonstrates the frequency of total ISM types. Totally 155 ISMs observed for 243 elements. The mostly observed ISM is intersemiotic complementarity. The number of observed semiotic adaption is 4, semiotic mixing mechanism is 7, 56 for semiotic transition and 31 for semiotic metaphor. Figure 4.11 monitors the average number of ISMs built for per text. The average number for intersemiotic complementarity is 7,1 per text, 0,5 for semiotic adaption, 0,9 for semiotic mixing per text, 7 for semiotic transition per text, and 3,8 for semiotic metaphor per text.

Table 4.13 Frequencies of intersemiotic mechanisms in the texts designed in the second iteration of HLT1

Participant	Text	Elements	IC	SA	SX	ST	SM	Total
All	1, 2, 3	Processes	3	1	2	26	15	47
		Participants	31	2	4	16	7	60
		Circumstance	23	1	1	14	9	48
		Total	57	4	7	56	31	155
		Average Per-	*7,12*	*0,5*	*0,9*	*7*	*3,9*	*19,3*

*IC: Intersemiotic Complementarity, SA: Semiotic Adaption, SX: Semiotic Mixing, ST: Semiotic Transition, SM: Semiotic Metaphor

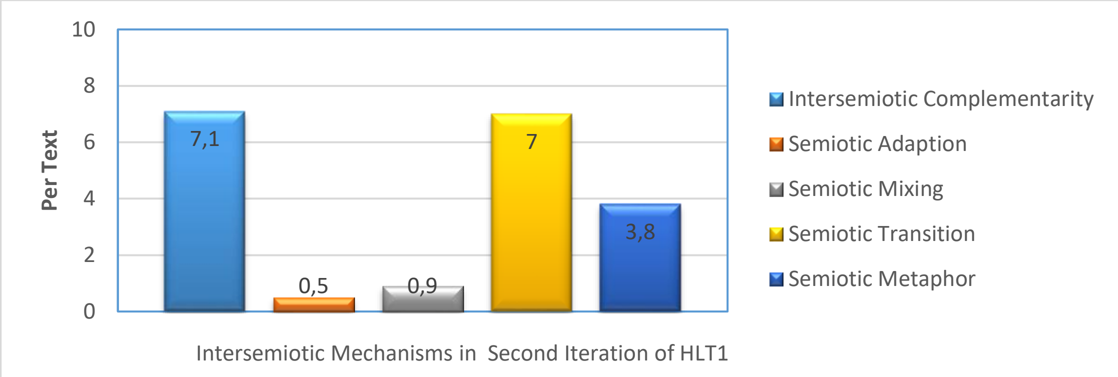

Figure 4.11 Frequency of ISMs per texts designed in the second iteration of HLT1

4.2.1.4 The Developmantal Trends for Paradigmatic Dimension Aspects

In this part, from the awareness part to the end of the intervention, whole participants' the development trends are demonstrated for each teach design competency aspects. The data gathered in the text analysis are demonstrated in total for all participatns.

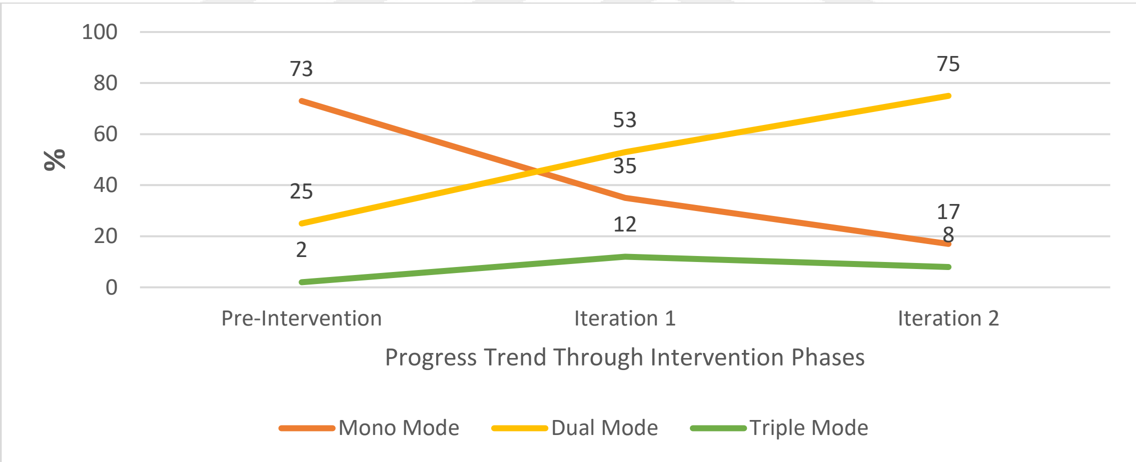

Figure 4.12 The developmental trends for mode levels in the progress of the intervention

Figure 4.12 above, the percentages of mode levels are presented in each phase of the implementation. The changes in mode levels are demonstrated. In the awareness phase (pre-intervention), 73 % of components were presented as mono-mode level. In the first iteration, 35 % of components were presented in mono-mode. In the second iteration, 17 % of components were presented in mono-mode. As can be seen, the number of mono-mode level components had been decreased in the progress of the implementation. When we look at the changes in the frequencies of dual-mode level components, we see an increase through the iterations. In the awareness phase, the percentage of dual-mode level components was 25%. This percentage increases to 53 % in the first iteration of HLT1. It is 75 % at the end of the second iteration.

The percentage of triple-mode components was 2 % in the awareness phase, 12 % in the first iteration, 8 % in the second iteration. In the triple-mode level components, language, visual imagery, and mathematical modes are used together to demonstrate at least one element in a component. The decrease of triple-mode components is seen expected since the content does not contain mathematical relations. This situation shows the conscious use of mode in text design. There observed an overall increase in the mode-level in the components. This means that participants used more than one mode to demonstrate content and increased the number of multimodal representations.

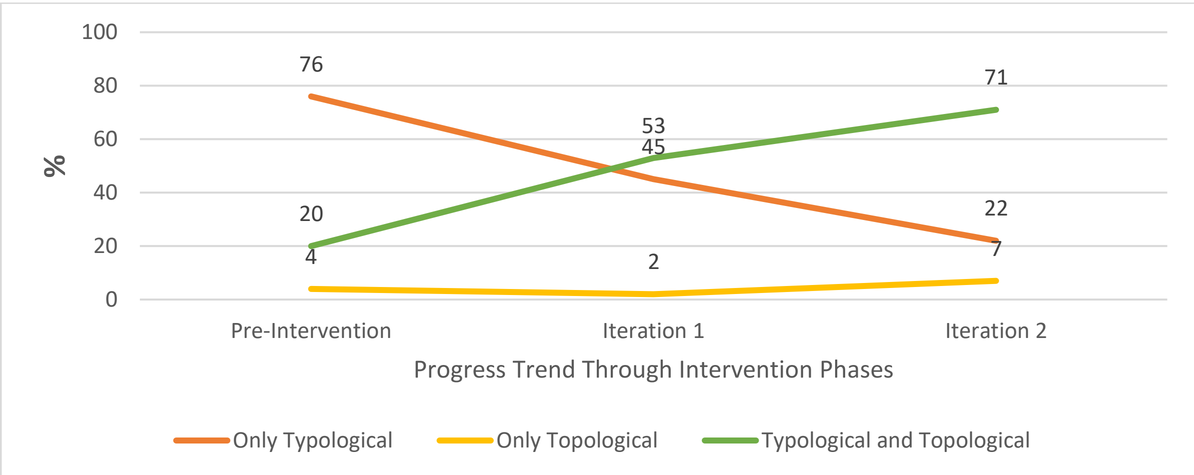

Figure 4.13 The developmental trends for use of meaning types in progress of the intervention

Figure 4.13 demonstrates the developmental trend in the meaning types in used modes in the components. For typological meaning, in the awareness phase, 76 % of components included representation that demonstrate only typological meaning. In the first iteration of HLT1, the percentage of components including only typological meaning decreased to 45%. In the second iteration, the percentage is 22%. In the progress of the implementation, the percentage of components having only typological meaning is decreased and the sharpest decrease was in the first iteration.

The percentage of components including only topological meaning was 4 % in awareness phase, 2 % in the first iteation, 7 % in the second iteration. The percentage of components representing the content by use of modes that include topological and typological meaning had been increased in the progress of implementation. The percentage of components involving typological and topological meaning together was 20 % in awareness step, 53 % in the first iteration, and 71 % in the second iteration. This means that the number of components where the meaning is contextualized and expanded through the progress of iterations.

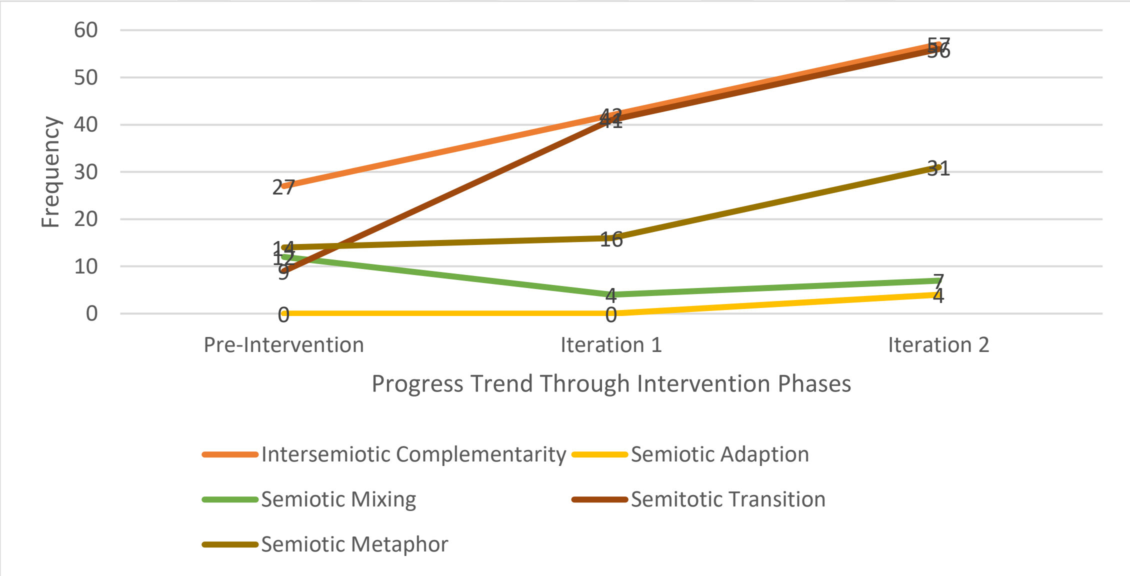

Figure 4.14 The developmental trends for ISM per text in progress of the intervention

Figure 4.14 demonstrates the average number of constructed ISMs in the multimodal representations. As can be seen in the chart, the variety and use of frequency is increased parallel to the increase in the mode level. One critical point here is that, the increase for all ISM types demonstrate that participants constructed different types of intersemiotic mechanisms to extend and contextualize meaning. They had not simply put a, for example, visual next to writing or formula next to visual. This aspect can be seen one guarantee of conscious design of multimodal ensembles in texts.

4.2.1.5 Demonstration of Transitivity System Elements

In this part, the mode levels in representation of transitivity system elements (participants, processes, and circumstances) are represented within developmental trends. The tables below show the change through pre-intervention, first iteration, and second iteration phases.

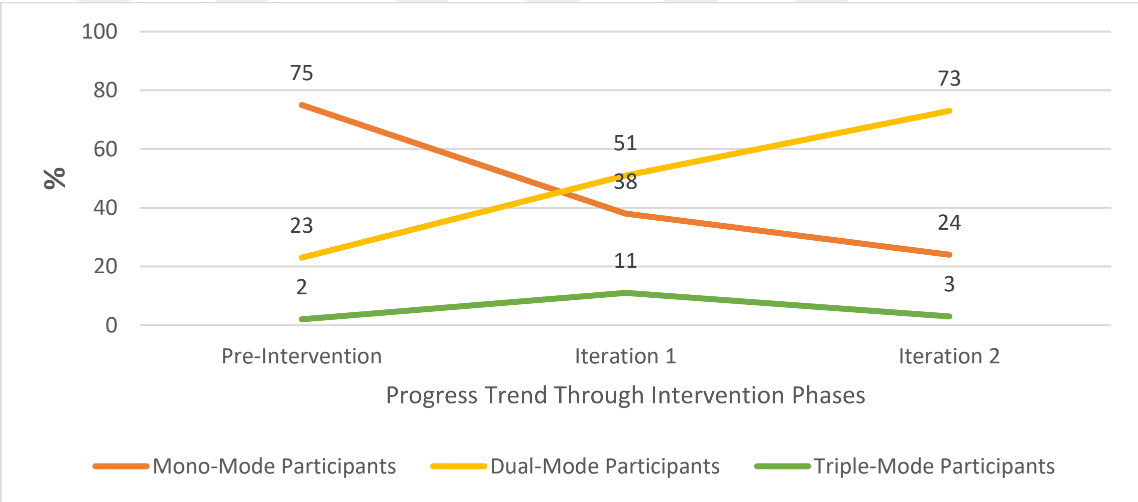

Figure 4.15 The developmental trends for mode levels in representation of participants

Figure 4.15 demonstrates that percentage of components that have mono-mode level representation of participants is 75 % in awareness phase, 38 % in the first iteration, and 24 % in the second iteration. For the components that have dual-mode level representation, the percentages are 23 % in awareness phase, 52 % in the first iteration, 73 % in second iteration. For the components that have triple-mode level representation, the percentages are 2 % in awareness phase, 11 % in the first iteration and 3 % in the second iteration.

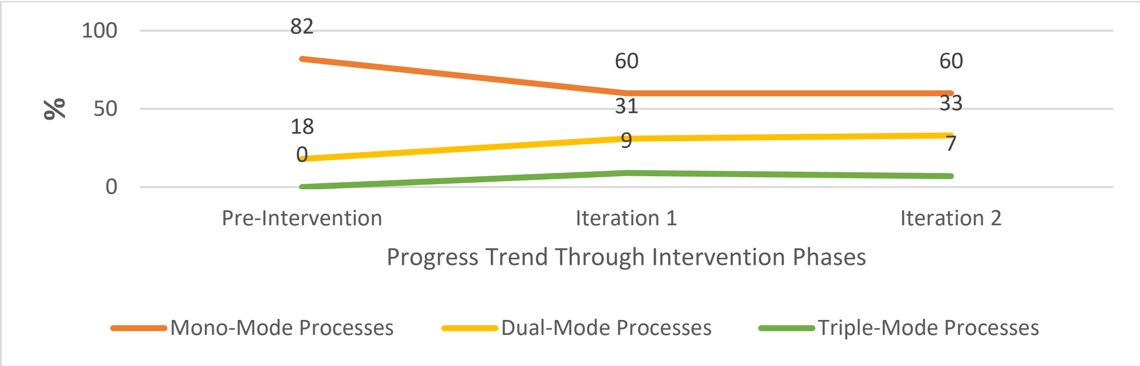

Figure 4.16 The developmental trends for mode levels in representation of processes

Figure 4.16 shows that percentage of components that have mono-mode level representation of processes is 82 % in awareness phase, 60 % in first iteration and 60 % in the second iteration. For the components that have at least one dual-mode level representation, the percentages are 18 % in awareness phase, 31 % in the first iteration, 33 % in the second iteration. For the components that have at least one triple-modelevel representation, the percentages are 0 % in awareness phase, 9 % in the first iteration, and 7 % in the second iteration. As can be seen the mode level in showing processes are lower than participants and circumstances. It was observed that language mode is dominantly used to demonstrate the processes in the texts.

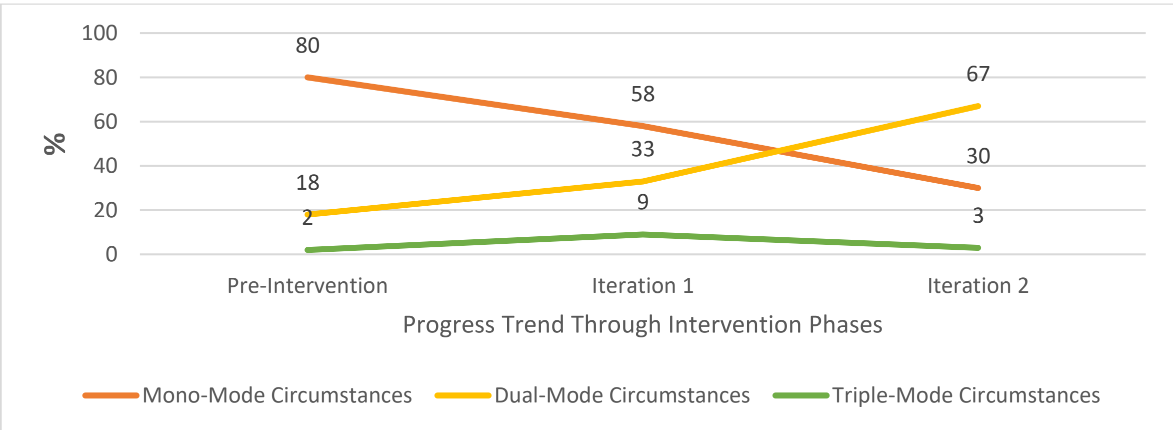

Figure 4.17 The developmental trends for mode levels in representation of circumstances

Figure 4.17 displays that percentage of components that have mono-mode level representation of circumstances is 80 % in awareness phase, 58 % in the first iteration, and 30 % in the second iteration. For the components that have at least one dual-modelevel representation, the percentages are 18 % in awareness phase, 33 % in the first iteration, 67 % in the second iteration. The sharpest change is observed in the second iteration. Therefore, it can be said that second iteration's effect is mostly observed in demonstrating multimodal circumstances in texts. For the components that have at least one triple-mode level representation, the percentages are 2 % in awareness phase, 9 % in in the first iteration, 3 % in in the second iteration.

Data demonstrates that the mode level in representations for all three transitivity system elements in DRAs increased in the progress of the intervention. Processes are transitivity elements, which are mostly demonstrated with mono-mode level (language mode). Circumstances are the second in the demonstration with mono-mode. From the awareness phase to end of the intervention, participants were the transitivity system elements that have highest mode level. This is because use of different modes is generally easier for participants, for example, language is presented with an exemplary picture or a mathematical symbolism in intersemiotic complementarity mechanism.

4.2.2 Findings of HLT2

4.2.2.1 Findings of Recognize Step of HLT2

In the recognize step of HLT2 two texts of same content with same semiotic resources and modes but different compositional aspects are presented, and open-ended discussion questions are asked. Regarding syntagmatic dimensions and effects of variation strategy in multimodal text composition on meaning making of science content is given below (see Appendix C). The data analysis created the aspects and themes regarding how variation strategy in compositional structure of multimodal pedagogic science text may make the content more understandable (see Table 4.14).

Table 4.14 Aspects and themes derived in the recognize part of HLT2

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

As stated earlier, we designed two multimodal pedagogic texts of "covalent bonding". For the first text, modes are chosen and randomly included in the text. For the second text, we have chosen modes as in the first case but we have designed the textual (compositional) meaning features of text according to variation theory of learning (Marton & Booth, 1997) and specific procedures proposed by Fredlund et al. (2015). Specific questions related to meaning making and understanding of the content were asked. By following the thematic analysis procedure mentioned above, we have firstly determined aspects and themes.

1. **Variation strategy may lead higher discernibility of critical aspects in multimodal pedagogic science texts.**

   This theme is related to potential of text structure to make the concepts, entities, or any of the aspects of the content discernible regarding their importance and criticalness. Since VTL emphasizes the degree of differentiation in the demonstration of content, variation level in the text is assumed to make the elements of content more discernible. As said earlier, this differentiation and discernment is expected to be built by foregrounding and relating to strategies within the text.

a. Critical aspects are viewed different in two cases.

This aspect deals with the perceived entities, concepts, and related aspects by the content. The most attractive factor to build this aspect is the difference of recognized concepts and related aspects between two texts. In the case of text 2, participants recognized additional concepts and aspects. Ebru, 3, 5, and 6 added extra concepts to in the second case (text 2). Some of the participant responses are given in below.

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

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

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

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

b. Hierarchy of criticalness is different in two cases.

This aspect is related to recognition and discernment of important and critical aspects of the content. As we stated earlier, all information or knowledge do not have similar importance. Texts have themes hand have a particular point to emphasize. Variation strategy is believed to foreground critical and important aspects of the content. We asked participants the criticalness hierarchy of information and knowledge embedded in the text. We asked same question for two cases. Participant mostly seemed to change their criticalness hierarchy. Below we present some changes from text 1 to text 2.

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

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

These findings shows that there happened changes in the views through which participants stated the critical aspects of the content.

2. Variation strategy can help to design complete and coherent multimodal pedagogic science texts.

This theme is related to completeness of the text that refers to "representational goals which instruct the model-maker to include every known aspect of the target system(s)" (Hay & Pitchford, 2016). I can be inferred that the representational form of the text should include all the information and aspects. Participants generally stated and implied that variation strategy may help to design a pedagogical multimodal text that are complete and inclusive. We constructed this theme by the determination of following thematic aspects.

a. More organized and coherent text structure.

This aspect is related to determining the aspect hierarchy before design of the text. Participants stated that by the dimensional and locational arrangements regarding criticalness hierarchy of aspects, the text structure becomes organized around a purpose.

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

b. Connections between smaller units

This theme is related to use of connections between the aspects of the text. In text 2, lines and arrows are used to relate and connect different information units of the text. Participants expressed that the content is more understandable due to the arrangement in connections and use of different semiotic resources for smaller units of the text. One participant view is expressed here as in below

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

Although almost all of participant commented on the text design strategy and emphasized aspects, only two Hasan and Eda attributed the related differences to dimensional and spatial differences of representations in the text structure. Others stated difference without giving sufficient reasoning. When we asked participants that which of the text they would choose if they taught this topic. All the participants chosen the second text that was designed regarding variation strategy.

Eda *stated that; …I would prefer second text because it has attractive text structure, contrasting options are more recognizable, text structure is more organized to make he intended meaning.*

4.2.2.2 Findings of First Iteration in HLT2

In this part, data gathered indesign step in the first iteration of HLT2 is presented. The data involves variation in component elements and the syntagmatic MDST aspects.

Table 4.15 Frequencies of variation types texts in the first iteration of HLT2

Participant	Text	Elements	Implicit	Explicit	Total
All	1, 2, 3	Processes	74	6	80
		Participants	70	10	80
		Circumstance	72	8	80
		Total	216	24	240
		%	***90***	***10***	

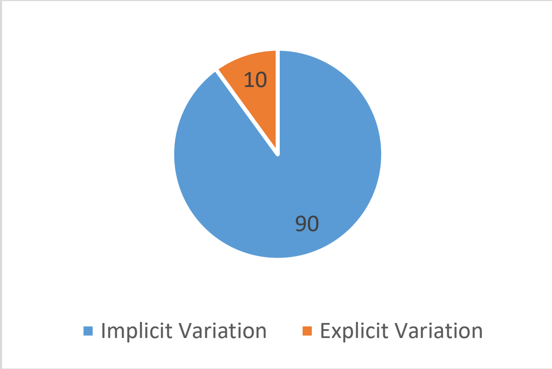

Figure 4.18 Variation types percentages in the first iteration of HLT2

Table 4.15 demonstrates the frequency of implicit and explicit variation observed in the components and elements. For the total processes, 74 elements out of 161 elements are implicitly variated, for participants the frequency for implicit variation is 70 out of 80, and for circumstance, the frequency of implicit variation is 72. Figure 4.18 demonstrates that 90 percent of total components are implicitly variated while 10 percent explicitly variated. This means that around one of ten element is explicitly variated.

Table 4.16 Frequency of compositional aspects in texts designed in the first Iteration of HLT2

		Placement of Text Elements			**Foregrounding / Backgrounding**			**Degree of Framing/ Relation**			**Heading/ Subheading**		**Relative Size**
Phase	Participant	L/R	R/L	Centering	Critical	Peripheral	No	Line Zones	Colored Zones	Arrow	Font Size	Font Color	Observed
Iteration 1	1			X	X	X		X	X	X	X	X	X
	2			X	X	X							
	3	X					x	X	X	X	X	X	
	4		X				x	X	X	X	X	X	
	5	X					X			X	X	X	

Table 4.16 Frequency of compositional aspects in texts designed in the first Iteration of HLT2 (cont'd)

Observed Total Frequency	3	1	2	2	2	3	3	3	4	4	4	1

Table 4.16 demonstrates the compositional aspects of all texts gathered in the awareness phase For the relative sizing of text elements, it was observed that only one of five texts employed relative sizing for demonstration of DRAs. Data demonstrates that, the number of texts that have centered orientation and use of relative sizing are comparatively low.

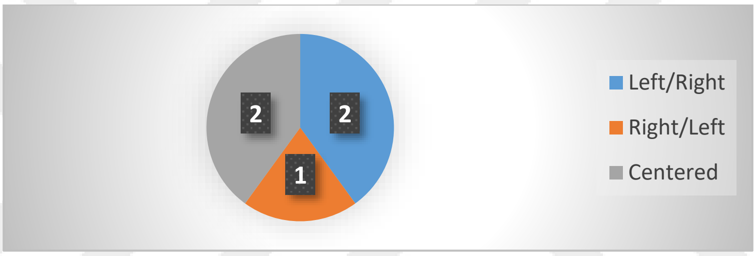

Figure 4.19 Text orientation percentages in the first ıteration of HLT2

Figure 4.19 demonstrates that the placement of text elements analyzed, it was observed that 2 of 5 (40 %) text are left/right oriented, one text is right /left oriented, and 2 of them (40 %) are center oriented.

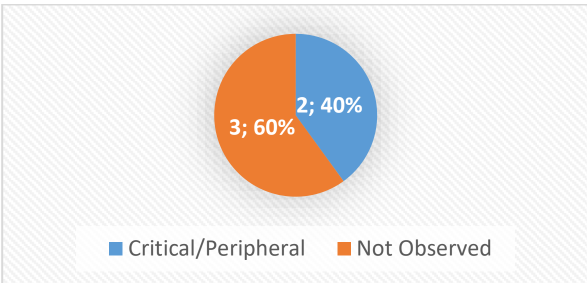

Figure 4.20 Percentages of texts regarding foregrounding/backgrounding in the first iteration of HLT2

Figure 4.20 shows that 2 of 5 texts (40 %) foregrounded the critical aspects and information of the content and backgrounded peripheral aspects. This means that two texts have compositional arrangements that purport to make DRAs more discernible.

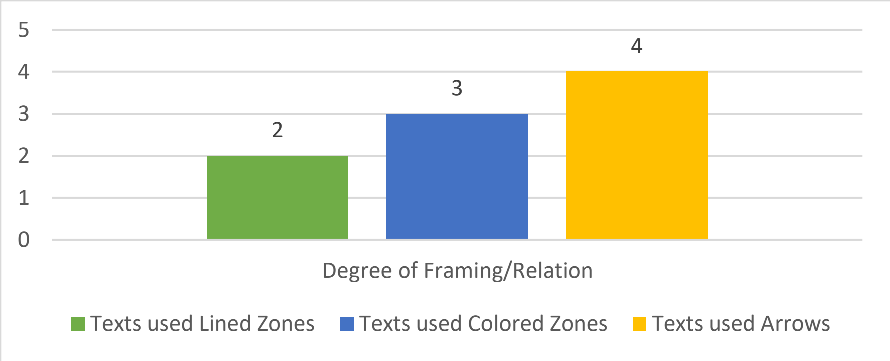

Figure 4.21 Percentages of texts regarding degree of framing/relation in the first iteration of HLT2

Figure 4.21 demonstrates the semiotic resources for framing and relating withing the text arrangement. For relating and separating the text elements, the degree of framing in the texts are observed as in following. 3 of 5 texts (60 %) used line zones and colored zones. In 4 of 5 texts (80 %), use of arrows was observed.

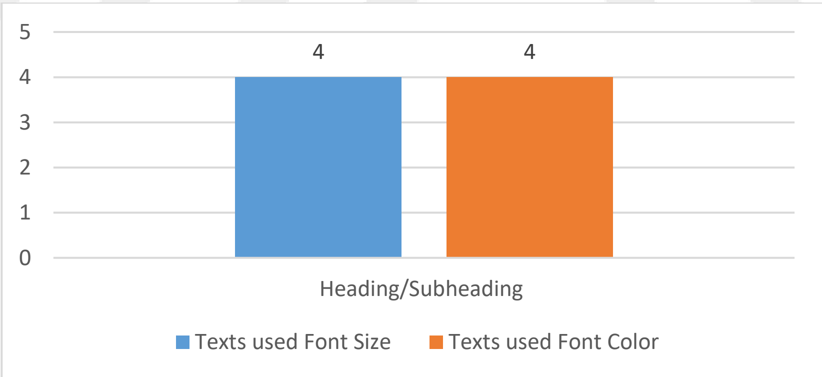

Figure 4.22 Frequencies of texts regarding heading/subheading in the first iteration of HLT2

Figure 4.22 demonstrates the frequency in the use of heading/subheading compositional strategy in the texts designed in first iteration. Data demonstrates that the use of different font sizes is observed in four 4 of 5 texts (80%). Similarly, four texts involve font coloring strategy as a composition strategy. This finding is similar to the finding gathered in the awareness (pre-intervention) phase.

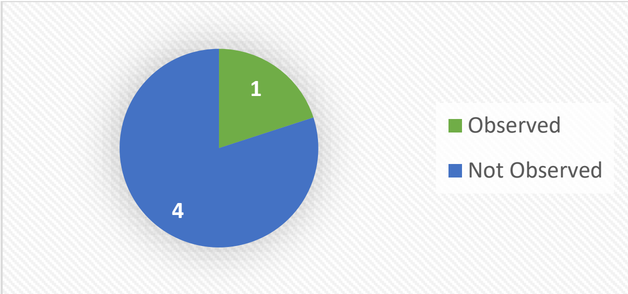

Figure 4.23 Frequencies of texts regarding relative sizing in the first iteration of HLT2

Figure 4.23 visualizes the use of relative sizing strategy for demonstrating DRAs. Data shows that in the first iteration only one of the five texts used relative sizing strategy in demonstrating text elements. As said earlier, critical DRAs are expected to be demonstrated bigger in relatin to other aspects.

4.2.2.3 Findings of Desing Step of Second Iteration in HLT2

Table 4.17 demonstrates the frequency of implicit and explicit variation observed in the components and elements. For the total processes, 156 elements out of 161 elements are implicitly variated, for participants the frequency for implicit variation is 141 out of 161, and for circumstance, the frequency of implicit variation is 153. Figure 4.24 below demonstrates that 93 percent of total components are implicitly variated while 7 percent explicitly variated.

Table 4.17 Frequencies of ideational variation types texts in the second iteration of HLT2

Participant	Text	Elements	Implicit	Explicit	Total
All	1, 2, 3	Processes	79	11	90
		Participants	77	13	90
		Circumstance	67	23	90
		Total	313	47	360
		%	***87***	***13***	

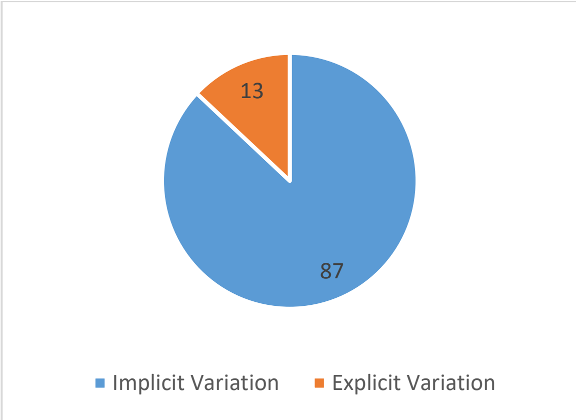

Figure 4.24 Variation types percentages in the second iteration of HLT2

Table 4.18 demonstrates the compositional aspects of all texts gathered in the awareness phase. For the relative sizing of text elements, it was observed that only one of five texts employed relative sizing for demonstration of DRAs. Data demonstrates that, the number of texts that have centered orientation and use of relative sizing are comparatively low.

Table 4.18 Frequency of compositional aspects in texts designed in the second iteration of HLT2

		Placement of Text Elements			**Foregrounding / Backgrounding**			**Degree of Framing/ Relation**			**Heading/ Subheading**		**Relative Size**
Phase	Participan	L/R	R/L	Centering	Critical	Peripheral	No	Line Zones	Colored Zones	Arrow	Font Size	Font Color	Observed
Iteration 2	1			X	X	X		X		X	X	X	X
	2			X	X	X		X	X		X	X	X
	3			X	X	X		X	X				X
	4	X					X	X	X	X	X	X	
	5	X								X	X	X	
Observed Total Frequency		2	0	3	3	3	2	4	3	3	4	4	4

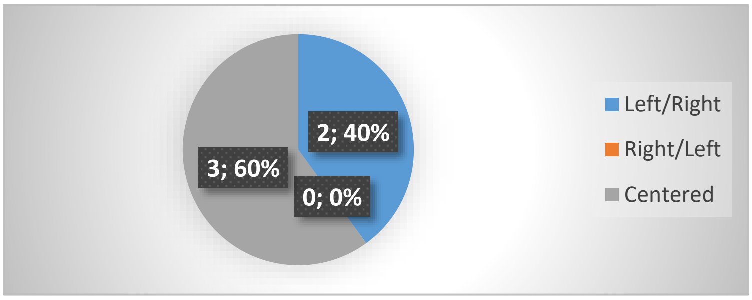

Figure 4.25 Text orientation percentages in the second iteration of HLT2

Figure 4.25 demonstrates that the placement of text elements analyzed, it was observed that 2 of 5 (40 %) text are left/right oriented, one text is right /left oriented, and 2 of them (40 %) are center oriented.

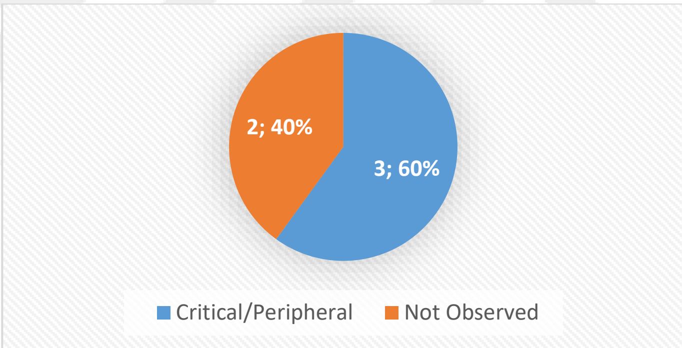

Figure 4.26 Percentages of texts regarding foregrounding/backgrounding

Figure 4.26 shows that 2 of 5 texts (40 %) foregrounded the critical aspects and information of the content and backgrounded peripheral aspects. This means that two texts have compositional arrangements that purport to make DRAs more discernible.

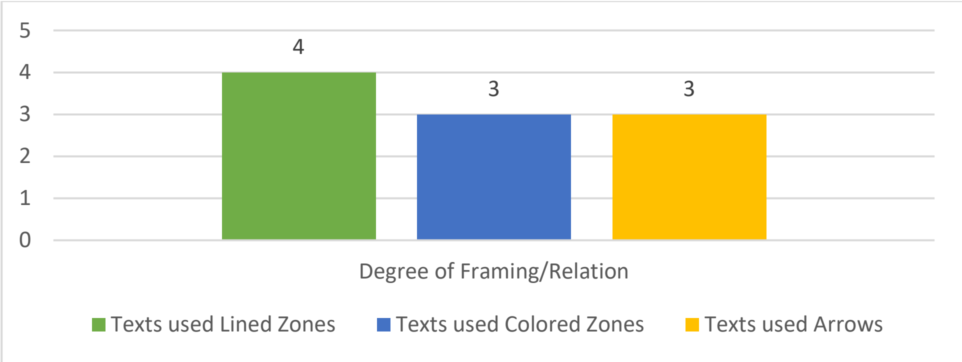

Figure 4.27 Percentages of texts regarding degree of framing/relation in the second ıteration of HLT2

Figure 4.27 demonstrates the semiotic resources for framing and relating withing the text arrangement. For relating and separating the text elements, the degree of framing in the texts are observed as in following. 3 of 5 texts (60 %) used line zones and colored zones. In 4 of 5 texts (80 %), use of arrows was observed.

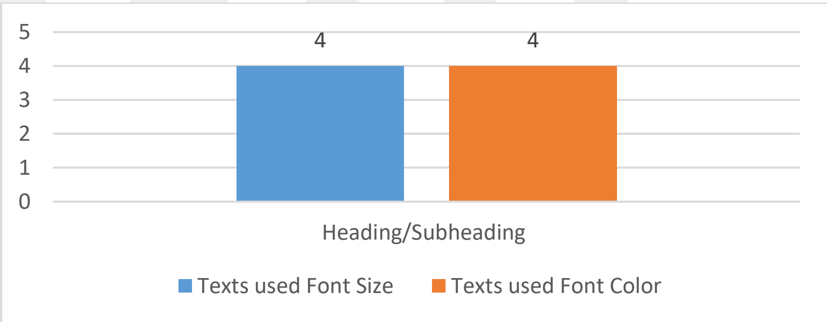

Figure 4.28 Frequencies of texts regarding heading/subheading in the second iteration of HLT2

Figure 4.28 demonstrates the frequency in the use of heading/subheading compositional strategy in the texts designed in first iteration. Data demonstrates that the use of different font sizes is observed in four 4 of 5 texts (80%). Similarly, four texts involve font coloring strategy as a composition strategy. This finding is similar to the finding gathered in the awareness (pre-intervention) phase.

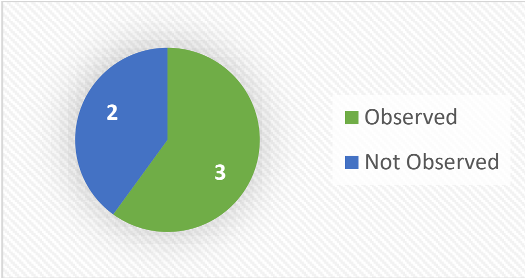

Figure 4.29 Frequencies of texts regarding relative sizing in the second iteration of HLT2

Figure 4.29 visualizes the use of relative sizing strategy for demonstrating DRAs. Data shows that in the first iteration only one of the five texts used relative sizing strategy in demonstrating text elements.

4.2.2.4 Findings of Desing Step of Third Iteration in HLT2

In this part, the analysis of text data gathered in the third iteration of HLT2 is presented.

Table 4.19 Frequencies of ideational variation types texts in the third iteration of HLT2

Participant	Text	Elements	Implicit	Explicit	Total
All	1, 2, 3	Processes	130	15	145
		Participants	118	27	145
		Circumstance	122	23	145
		Total	370	65	435
		%	***85***	***15***	

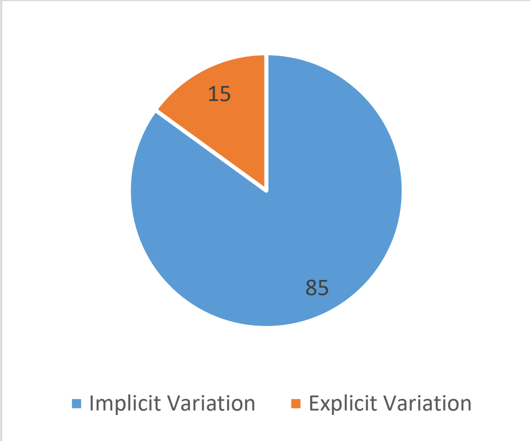

Figure 4.30 Ideational variation types percentages in the third iteration of HLT2

Table 4.19 demonstrates the frequency of implicit and explicit variation observed in the components and elements. For the total processes, 130 elements out of 145 elements are implicitly variated, for participants the frequency for implicit variation is 118 out of 145, and for circumstance, the frequency of implicit variation is 122. Figure 4.30 demonstrates that 85 percent of total components are implicitly variated while 15 percent explicitly variated.

Table 4.20 Compositional aspects in texts designed in the third iteration of HLT2

			Placement of Text Elements			**Foregrounding / Backgrounding**			**Degree of Framing/ Relation**			**Heading/ Subheading**		**Relative Size**
Phase	Participant		L/R	R/L	Centering	Critical	Peripheral	No	Line Zones	Colored Zones	Arrow	Font Size	Font Color	Observed
Iteration 3	1	*T1*			X	X	X		X	X	X	X		X
		T2			X	X	X		X	X		X	X	X
	2	*T1*			X	x		X	X			X	X	X
		T2			X	X	X		X	X	X	X	X	X
	3	*T1*			X	X	X				X	X		X

Table 4.20 Compositional aspects in texts designed in the third iteration of HLT2 (colt'd)

		T2			X	X	X		X	X	X	X	X	X
	4	*T1*			X	X	X			X	X	X	X	X
		T2			X	X	X		X	X	X	X	X	X
	5	*T1*			X	X	X	X			X	X	X	
		T2			X	X	X				X	X	X	X
Observed Total Frequency			0	0	10	10	10	0	7	6	8	10	8	7

Table 4.20 demonstrates the compositional aspects of all texts gathered in the third iteration of HLT2. The observed compositional MDST aspects seem relatively higher with regard to first and second iteration. The most critical finding here is that all of the texts are centered oriented and critical aspects are foregrounded.

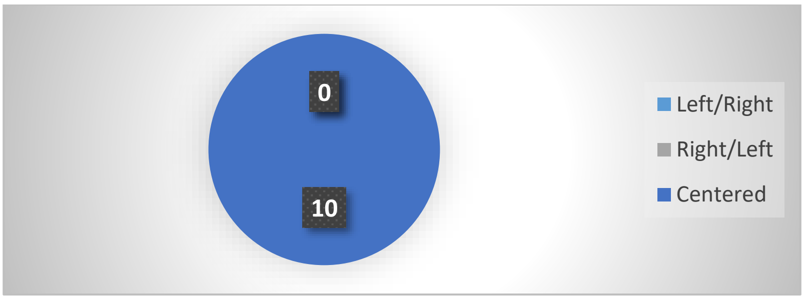

Figure 4.31 Text orientation percentages in the third ıteration of HLT2

Figure 4.31 demonstrates that the placement of text elements analyzed, it was observed that all ten texts are centered oriented. There is no text which is left/right or right/left oriented. According to the interview data, participants generally state that the placement of text element and the spatial relation between them were arranged to make the critical aspects more discernible.

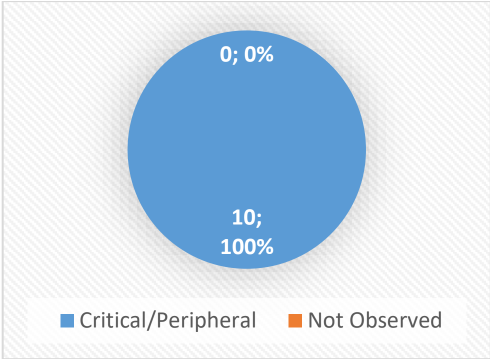

Figure 4.32 Percentages of texts regarding foregrounding/backgrounding in the third iteration of HLT2

Figure 4.32 shows that all texts are designed in a way which foregrounded the critical aspects and information of the content and backgrounded peripheral aspects. Beside the centered text orientation, use of this strategy is increased.

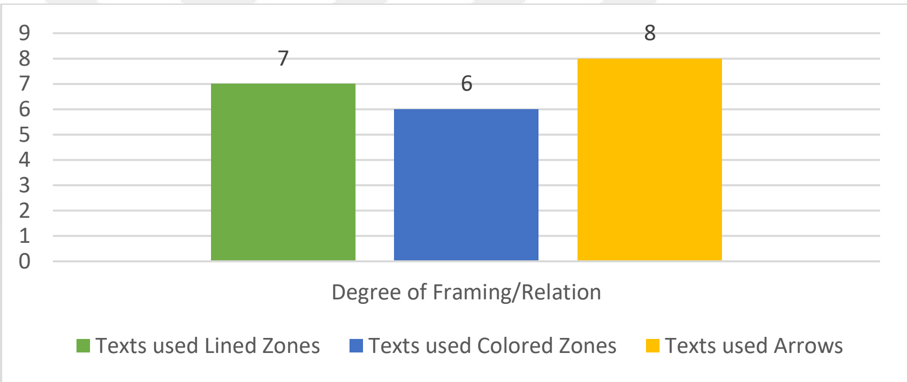

Figure 4.33 Percentages of texts regarding degree of framing/relation in the third iteration of HLT2

Figure 4.33 demonstrates the semiotic resources for framing and relating withing the text arrangement. For relating and separating the text elements, the degree of framing in the texts are observed as in following. 6 of 10 texts (60 %) used line zones and colored zones. In 8 of 10 texts (80 %), use of arrows was observed. This finding is similar to data gathered in the awareness, first iteration, and second iteration of HLT 2.

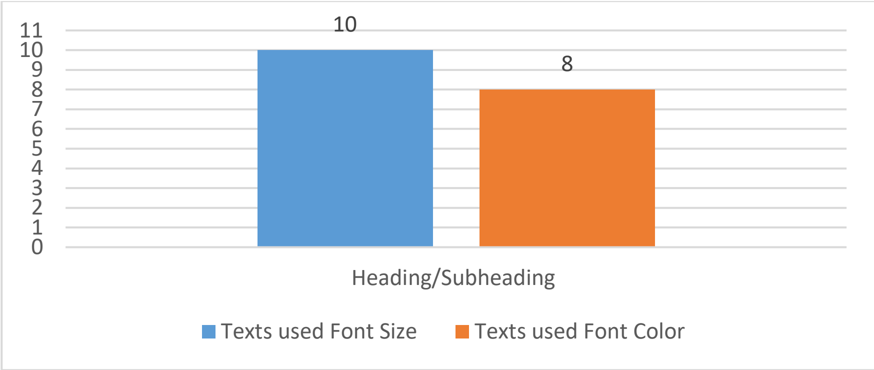

Figure 4.34 Frequencies of texts regarding heading/subheading in the third iteration of HLT2

Figure 4.34 demonstrates the frequency in the use of heading/subheading compositional strategy in the texts designed in first iteration. Data demonstrates that the use of different font sizes is observed in four 4 of 5 texts (80%). Similarly, four texts involve font coloring strategy as a composition strategy. This finding is similar to the finding gathered in the awareness (pre-intervention) phase.

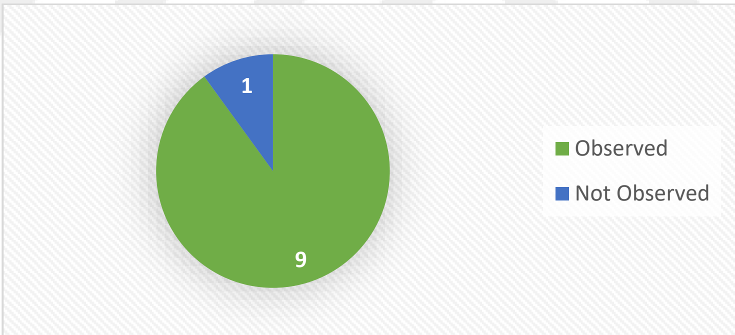

Figure 4.35 Frequencies of texts regarding relative sizing in the third iteration of HLT2

Figure 4.35 visualizes the use of relative sizing strategy for demonstrating DRAs. Data shows that in the third iteration nine of the ten texts used relative sizing strategy in demonstrating text elements. There is a sharp increase with regard to first and second iterations. The use of relative sizing with centered text orientation and foregrounding is increased along with the iterations.

4.2.2.5 Developmental Trends for HLT2

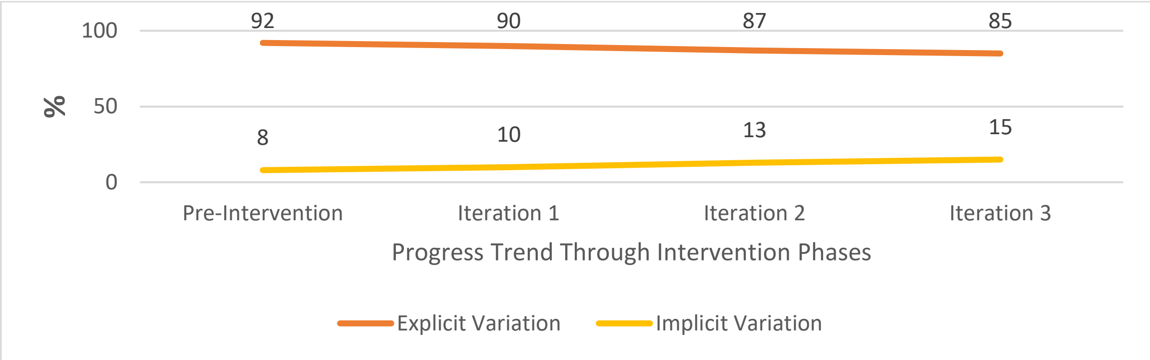

Figure 4.36 The developmental trends for ideational variation in progress of the intervention

Figure 4.36 demonstrates the the creation of ideational variation around the aspects at component level. In the progress of the implementation there observed increase in the number of components where explicit variation is created and decrease in the number of the components where implicit variation is created. For the implicit ideational variation, the percentage of components was 92 % in the awareness phase, 90 % in the first iteration, 87 % in the second iteration, and 85 % in the third iteration. In parallel, the percentages for explicit variation was 8 % in the awareness phase, 10 % in the first iteration, 13 % in the second iteration, and 15 % in the third itearation.

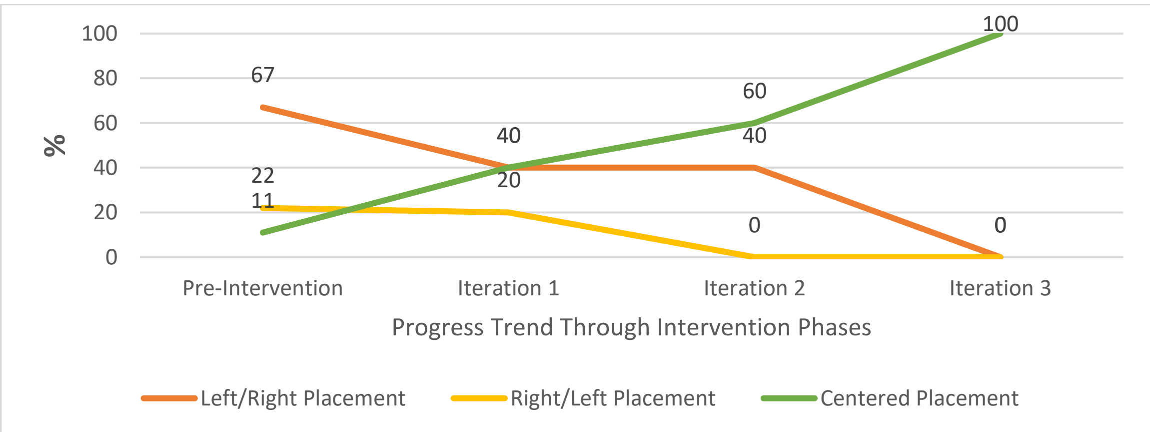

Figure 4.37 The developmental trends for placement of text elements in the texts

When the progress is analyzed in the Figure 4.37, it can be seen that the majority of the texts were composed in left/right placements (67 %) in awareness phase. The second frequent placement strategy was right/left (22 %), and the third was centering placement (14 %). The percentage left/right placement decreased to 40 % in the first iteration. In te second iteration, left/right placement was the same with the first iteration. In the third iteration, no text having left/right placement was observed. The percentage right/left placement increased fron 11 % to 20 % in the first iteration. In the second and third iterations, texts having right/left placement were not observed. The percentage of texts that are centered-oriented was 11% in the awareness phase, 40 % in the first iteration, 60 % in the second iteration. In the third iteration, all the texts were centered oriented.

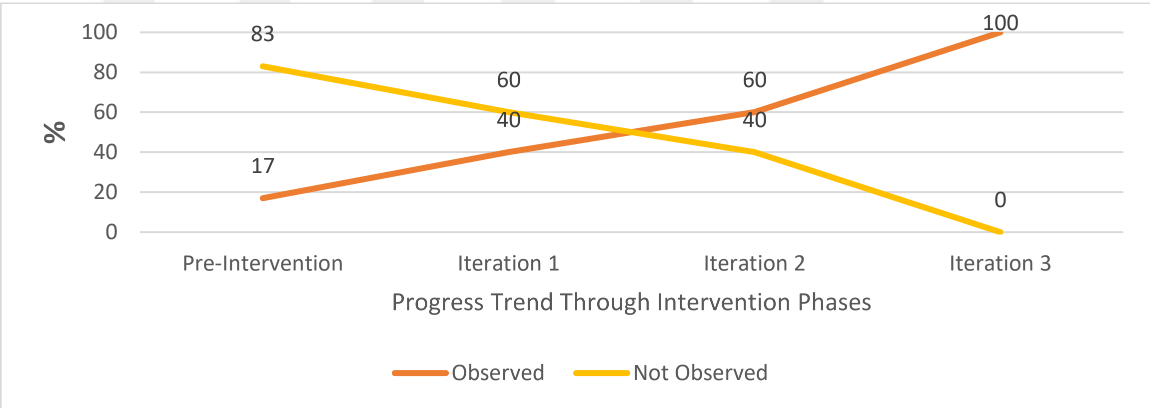

Figure 4.38 The developmental trends for criticalness hierarchy

Figure 4.38 demonstrates how the compositional aspects of the text demonstrate the criticalness hierarchy of the aspects of the content. The analysis demonstrates the percentages of texts which demonstrates criticalness hierarchy and which does not. This is done by foregrounding the critical aspects to make them more discernible and backgrounding the peripheral aspect to make them less discernible in a comparison to critical aspects. The change trend demonstrates that in the awareness phase % 17 of the total texts made the critical aspects more discernible by text composition. This percentage is increased to 40 % in the first iteration, 60 % the second iteration, and 100 % in the third iteration.

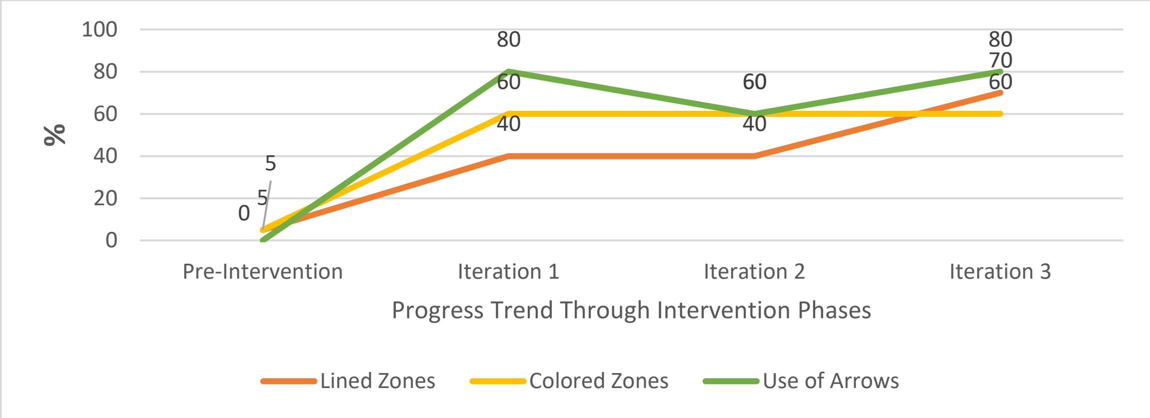

Figure 4.39 The developmental trends for degree of framing / relation of text components

Figure 4.39 demonstrates the progress of the percentage of texts where the degree of framing elements observed in the text composition. As said earlier, these strategies functions to relate different meaning units (components, items, or micro-genres) in the text. For the use of lined zones, the percentage of texts was 5 % in awareness phase, 40 % in the first iteration, 40 % in the second iteration, and 60 in the third iteration. For the use of colored zones, the percentage of texts was 5 % in awareness phase, 60 % in the first iteration, 60 % in the second iteration, and 70 in the third iteration.

For the use of arrows, the percentage of texts was 0 % in awareness phase, 80 % in the first iteration, 60 % in the second iteration, and 80 in the third iteration.

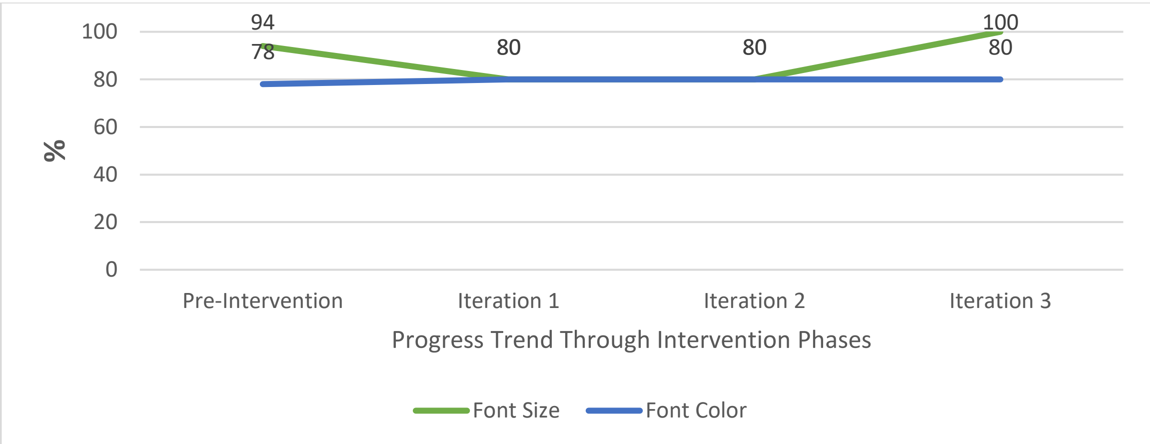

Figure 4.40 The developmental trends for of headings and subheadings and relative sizing

Figure 4.40 displays the percentages of the texts where the font sizing and font coloring strategies for headings and subheadings are used and the texts where relative sizing of text elements (parts) is done. For the use of font size, the percentage of texts was 94 % in awareness phase, 80 % in the first iteration, 80 % in the second iteration, and 100 in the third iteration. For the use of font color, the percentage of texts was 78 % in awareness phase, 80 % in the first iteration, 80 % in the second iteration, and 80 in the third iteration. Font sizing, font coloring, and relative sizing of text parts are the most salient compositional aspects of the texts designed in pre-intervention or awareness phase. During the design interventions, participants were not specifically and directly trained for the use of these text composition aspects. However, the strategies derived from VTL implicitly affected participants to arrange these aspects of text composition. For example, in efforts for making the critical aspects more discernible in the texts reflected to the headings next to critical aspects

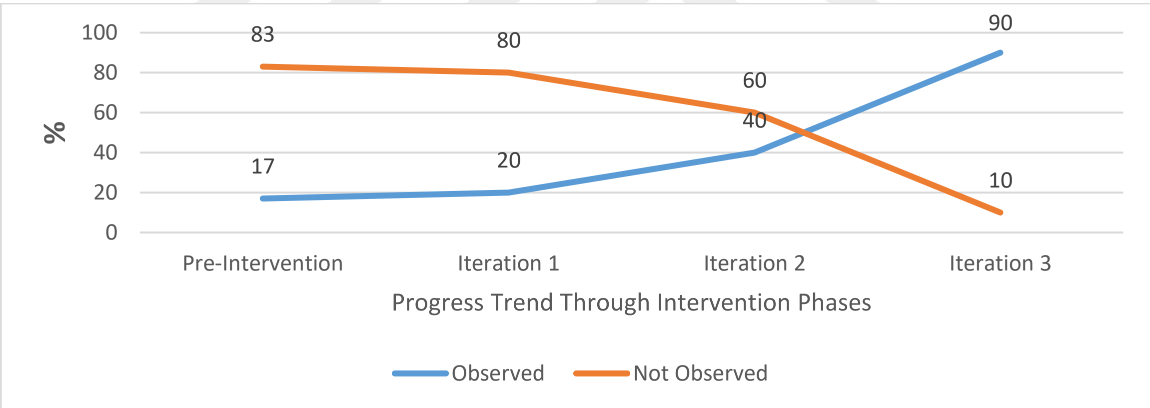

Figure 4.41 The developmental trends for relative sizing

Figure 4.41 demostrates the percentages of the texts where relative sizing is used or not used. For the use of relative sizing, the percentage of texts was 17 % in awareness phase, 20 % in the first iteration, 40 % in the second iteration, and 90 in the third iteration. The sharp increase from second iteration to third iteration demonstrates the effect of direct instruction on the use of relative sizing with respect to the the criticalness hierarchy.

4.2.3 Post-Intervention Interviews

After the intervention, individual interviews were done to explore participants' views about views and strategies in designing MDSTs. Besides the texts they designed in the intervention, these interviews functions to deeply understand their text design strategies and evaluate the development in multimodal text design competencies. Each participant was individually interviewed with semi-structured open-ended questions. The interview data is thematically analyzed, and common themes and aspects are demonstrated with relevant headings below. Table 4.21 demonstrates that participants developed a pedagogical strategy in designing MDSTs and they value the effects and role of these texts in the meaning making of content and learning products of students.

Table 4.21 Participant responses given related themes in the post-intervention interviews

Theme		Hasan	Ebru	Sude	Eda	Cem
1	Participants developed and explicit didactic multimodal text design strategy for their teaching practices.	X	X	X	X	X
2	Participants expresses that the science texts used in the instructions, or any lesson activity can affect meaning making of content and quality of learning products regarding creativity.	X	X	X	X	X
3	Participant posit that multimodal texts can enhance learning of scientific concepts and knowledge.	X	X	X	X	X

Participants developed and explicit didactic multimodal text design strategy for their teaching practices.

During the interviews, participants are explicitly asked with whether they have a pedagogic strategy in designing MDSTs. They generally gave similar responses that include conscious and consistent views. It was generally observed that participants feel more confident when they choose and design science texts in a comparison to the initial statements. The general statements about test design strategy includes choosing the modes that have best meaning making potential (affordance) and arranging the compositional aspects of the text according to the criticalness hierarchy of the information and knowledge in the text. In below some responses are given.

> ***Hasan:*** *When I decide the learning goals and content, I choose various modes that can meet my teaching aims. Afterwards, I focus on compositional aspects of the texts that need to foreground and highlight the critical aspects of the content. I use variation strategy in text to increase the discernibility of the aspects in the content.*
>
> ***Sude:*** *Firstly, l determine the critical and important aspects of the content and arrange the compositional aspects of the text according to this hierarchy. Afterwards, I try to define the modes that have best meaning making potential. For example, if there is quantitative relationship in the content, I prefer mathematical mode. If there is an abstract entity, I try to use visual imagery mode to concretize (contextualize) the content. I try to be careful about the relation between modes and I do not want to integrate modes that are irrelevant about content to each other.*
>
> ***Eda:*** *The first thing I want to do is to determine the concepts, entities, and processes in the content. Afterwards, I determine critical aspects in the content and the criticalness hierarchy. Then I choose the modes to represent the aspects in the content. For example, if the content needs a visual image (since it has best potential), I choose a visual image or if the content needs to be represented by a mathematical formula, I use it. Afterwards, I try to make a coherency in the composition of the text, which are made of those modes. After this training*

program, I realized that I obtained a criticizing eye when I select a representation even I am doing something irrelevant to teaching.

Cem: *I realized that my previous text design strategy was not systematical and random. Now, I have learnt that each mode have its own meaning making potential. Therefore, when I make choices of meaning resources in text design, I firstly consider this. Then I consider the aims of the content (criticalness of contents in the text is implied). Afterwards, I try to design a text where chosen modes are concordant with each other, not isolated. This strategy fits to me and I will follow it. Additionally, I will be careful about the economy principle in the text. Furthermore, I think to teach my students this multimodal text design strategy when they design their learning assignments and products.*

Participants expresses that the science texts used in the instructions, or any lesson activity can affect meaning making of content and quality of learning products regarding creativity.

In the interviews, participants are asked that "How can the texts used in the classroom affect the meaning making of the content and scientific knowledge?". Participants generally responded that, if they choose or design a meaningful science text, student understanding of the content and scientific knowledge. Therefore, they posit that text they use during instruction, or any teaching activity is a part of student learning of science concepts. Some examples of participant responses on how participants think about these points.

Ebru: *Since it demonstrates the content in a meaningful and understandable way, a well-designed instructional text can enhance the meaning making and learning of the content. Furthermore, since I have developed a critical thinking skill towards for meaning making and the use of resources, I have become skeptic to other resources such as tools that I use in my lessons.*

Eda: *Use of various modes can help students to learn unfamiliar and abstract contents. Using one mode is insufficient to demonstrate some knowledge. For example, visual images help to me to demonstrate the phenomenon itself (topological meaning), and then concretize what is going on. Mathematical* *formulas help to see the process in a short and synoptic view. Language is quite important since we provide knowledge about the content (typological meaning). In other words, all these modes have their own strengths and using just one of them is sufficient to demonstrate the meanings embedded in the content. Furthermore, a well-designed text helps to demonstrate the content in a systematic structure.*

Sude: *when I present some information or scientific knowledge in only language mode, it is difficult for students to imagine and understand what is going in the content or how actually the phenomenon is. Therefore, this situation reflects to students' learning products or designs created in lesson activities. Multimodal texts can help to produce creative learning products because it gives many resources for imagining the content and student can use these resources to produce new designs.*

Participant posit that multimodal texts can enhance learning of scientific concepts and knowledge.

It was generally stated that multimodal texts are learning resources which can enhance understanding and meaning making of science content in various ways. Some responses are given in below.

Sude: *Multimodal texts can increase retention of scientific knowledge in cognitive structure. Because it concretizes and make it easier to understand the information (typological and topological meaning at the same time). Each mode has their own affordances and multimodal texts can provide the information with best affordance.*

Cem: *Multimodal texts address a wide variety of perceptual systems and intelligence types since they present information by use of various communication tools. This is specifically important gifted science classroom where students have diverse types of perceptual systems and intelligences.*

Hasan: *Multimodal text can demonstrate information in an economic way because they can represent the content without use of many resources. If we* *choose the modes that have best representation power, then students can understand the content in a shorter time in a comparison to monomodal texts.*

These interview data revealed that participants teachers embraced a MDST design strategy when they chose or design didactic or instructional texts. Furthermore, teachers recognized the nature and power of multimodal texts in learning of science concepts. Finally, teacher realized they ways in which didactic science texts influence the learning of the content and learning products designed by students.

4.2.4. Evaluation Interviews in the Progress of the Implementation

The implementation has diverse aspects. The first includes duties and responsibilities of researcher and participants. Second, aspects include the pedagogical aspects of design activities in different parts of HLTs. These contain, the learning materials (given texts, video instructions), feedbacks, and evaluation interviews. The third aspect includes the schedule and time management. This aspect includes whether the allocated time for each activity is enough to complete because the learning and design activities are conducted in virtual platforms. Fourth aspect involves tools, applications, media used to communications, design, share, and evaluation.

In the progress of the implementation, and interviews on these aspects were done. For the first aspects, participants generally found the roles and responsibilities of researcher appropriate and successful. Since the researchers was always in-touch via various communication tools (e-mail, instant messaging, video meeting, or telephone call) when participants faced any difficulty or problem with instructions, designs activities or any technical issue, researcher was ready to help. This facility helped to keep the progress on the track in terms of both timing and appropriate participant performance.

For the second aspect, participant expressed some difficulties. As stated earlier, the HLTs include overt instruction phase and this phase include video instructions prepared by the researcher. In the first evaluation interview, almost all the participants expressed that a handbook can be better next to video, especially when they design text. Researcher developed a MDST handbook with exemplary exercised. In the following iterations, the efficiency of handbook is observed. Secondly, it was realized that video instruction and handbook were still insufficient in HLT2. Researcher decided that a live video instruction on the explicit instructions on compositional aspects of meaningful multimodal science text should complement video instruction and handbook. In the following iterations of HLT2. Participant difficulties and evaluations of their text designs helped to improve this part of the HLTs. Third aspect include the time management and sufficiency of given time gap for the learning and design activities. Participants generally stated that the allocated time for design activities is enough and precisely informed in the implementation plan. However, they said that they sometimes have difficulties in sparing time due to their other works and lessons in the schools. Therefore, it was decided to extend deadlines for the following iterations.

For the design activities, instructions and share of information certain tools, applications, and platforms chosen and introduced to participants before the implementation. The main platform is a virtual classroom (asynchronous) which enables to assign homework, design, and upload instructions by used of a high variety of media, and production tools for designing texts. In the progress of the intervention, participants found that, the production tools are insufficient for designing texts that they planned. Therefore, participants are provided with more applications with text design tools. The selected tools enabled participants design multimodal texts with more fine-grained compositional aspects such as locating and sizing the text elements and relating different parts of the text by colored zones and use of arrows. The evaluation interviews for the implementation process were quite crucial to take reflections and feedbacks to develop the implementation procedure and content. For the maturing and developing of the draft intervention model, the data gathered through evaluation interviews and participants' competence levels in designing multimodal science texts parallel to learning goals were main monitors.

4.3 Individual Progress

In this part, four participant's texts and individual progress presented. These four participants are randomly chosen. The texts are qualitatively analyzed, and the analysis is supported with interview data. In addition, the developmental progress of these four participants is presented quantitatively. There is one text for awareness phase and three texts for all HLTS. The analyzed texts are those, which are designed at the end of each HLT. The data showing the individual progress is gathered from all texts designed by participants in each phase.

a. Hasan's Progress

1. Hasan's Texts

Text 1 is designed by Hasan in awareness phase and the text was designed it for actual teaching practice.

Figure 4.42 Hasan's text designed in the awareness phase

The text in Figure 4.42 has totally 10 components. The subject of the text is "Fungals". The thematic patterns of DRAs shows that scientific knowledge in each component is demonstrated by mono-mode representation in language mode. The text is totally monomodal. The cross-semantic mapping of the text yields that, all transitivity system elements are represented with written language mode. Therefore, there is not any ISM constructed. Regardign the metafunctional organization, the knowledge is presented with the semiotic resources and modes, which involve only typological meaning. Therefore, the ideational meaning is not contextualized and extended. As such, mixed-mode semiosis is not observed. Furthermore, the ideational variation is implicit in all components. This text is assumed as having low meaning making potential and having limited number of semiotic resources and modes regarding kinds. Therefore, it is also assumed that it can provide limited resources for students to produce creative learning outcomes.

In terms of compositional aspects and text structure sytagmatic dimension, placement of text elements is left/right placement. The foregrounding and backgrounding of aspects according to criticalness hierarchy and degree of framing elements are not observed. The compositional aspects that help to be more meaningful are font sizing and font coloring of the heading. What is more the different knowledge parts of the text are separated by use of different coloring in the clauses. There is no relative sizing in the text. The compositional aspect of the text is evaluated to be low to support meaning making of the content.

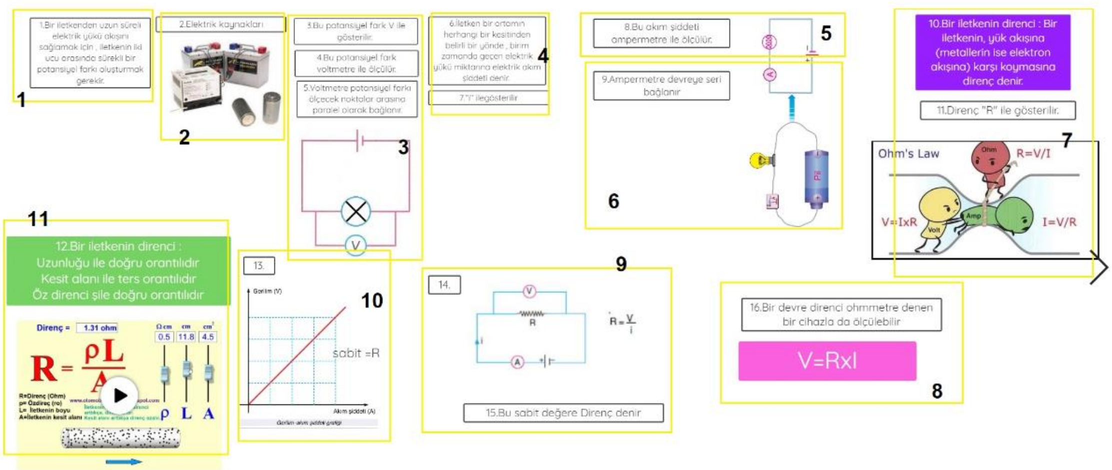

Figure 4.43 Hasan’s text designed in the HLT1

The text in Figure 4.43 has totally 11 components. The subject of the text is Ohm's Law. The cross-sematic mapping of DRAs shows that there are totally two components, which are represented with mono-mode level representations. Six components are represented in dual-modelevel. For example, in component 2, the participants are represented with language mode and image mode. Two modes complement each other in intersemiotic complementarity mechanism to demonstrate the participant "battery". What is more, in component 5, the concept of "circuit" is demonstrated with language mode and visual imagery mode, which is a form of disciplinary way of representation. Therefore, the intersemiotic mechanism type is semiotic transition. There are three components including triple-moderepresentation. For example, in component 7 the concept of "resistance", passing of electrons and the circumstance where the process is taking place are represented by three modes. The intersemiotic mechanisms are semiotic metaphors where, for example, circumstance of difficulty of passing of electrons is represented with a bottleneck. In the text, language, visual imagery, and mathematical modes are collaborated in various intersemiotic mechanisms and through these mechanisms meanings in components are extended. The by the use of multimodal representations, the meanings in components are mostly demonstrated by typological and topological meaning. This means that the mixed-mode semiosis takes place in these components. The creation of mixed-mode semiosis leads to contextualization of meaning which helps the readers of the text make meaning of the content easier.

The compositional aspect of the text includes following features. The text has both left/right and light/left placement of text elements. The upper part of the text has left/right, and the lower part is right/left oriented. The foregrounding and backgrounding of aspects according to criticalness hierarchy are not observed. Regarding degree of framing, the text parts are separated with lined zones and colored zones. These lined zones and colored zones are also ways of relation since the separated zones are put in a chain of knowledge flow where adjoining zones are related to each other. There was not any font sizing and coloring for heading and subheading. In the text, the relative sizing of the text parts observed. However, this relative sizing is not to make the critical aspects discernible since the criticalness hierarchy is not constructed through text composition.

In sum, the text can be considered as rich in terms of mode level, semiotic resources and constructed intersemiotic mechanism types. However, the compositional aspects of texts seem not having enough quality to demonstrate the critical aspects which students need to focus on more and need to be aware of more. The variation strategy in text composition is not observed.

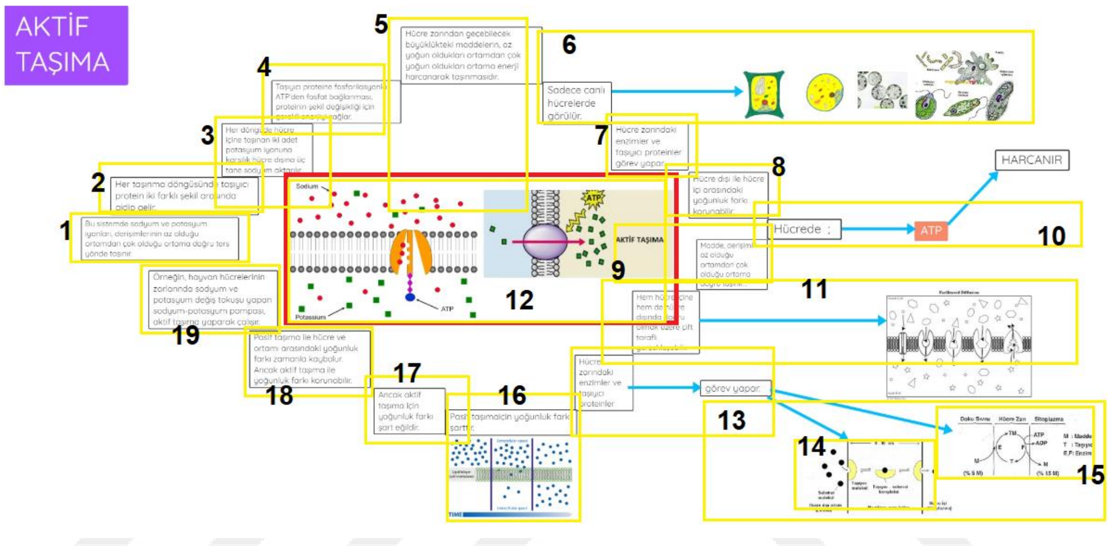

Figure 4.44 Hasan's text designed in the first iteration of HLT2

This text has 15 components. The subject of the text is "Active Transition". The cross-sematic mapping of DRAs shows that ten of the components are designed as dual-modeand remaining components are mono-mode (monomodal). The common intersemiotic mechanism used in the text is the intersemiotic complementarity where exemplary instances of any transitivity element is given. For example, in component 6, exemplary pictures of participant and circumstance is given. Component 16 is a good example where the circumstance of action is demonstrated with language and visual imagery in intersemiotic complementary mechanism. The collaboration of language and visual imagery here provided both typological and topological meaning where students experience both scientific knowledge with the corresponding meaning as how it takes place in the real world. In component 10, semiotic mixing intersemiotic mechanism is used to demonstrate meaning. The arrows in the component represent processes. This text can be considered as rich in terms of ideational variation. For example, contrasting options of participants and circumstance are given in component 13. The process of “active transportation”, its participants and circumstances are visualized with two colored cartoonish drawings. While the first drawing focused on the process, the second drawing focuses on the consumption of energy in the process. Other knowledge pieces (meaning units) are put around these visual images and commonly used. This created a semiotic economy whereby the use of less semiotic resources, more meaning and information provided.

In the interview, the main strategy in designing of this text is asked to the participant. The response is given below.

> ***Hasan:*** *I firstly group the information (meaning units), then I decided to put a visual which demonstrates active transport and consumption of energy. Afterwards, I tried to use different modes to increase the meaningfulness… I notices to create a meaning coherency among the modes I use (topological and typological meaning is implied). Since I considered the consumption of energy as the most important aspect, I provided different instances and examples where ATP (energy) is consumed.*

Regarding compositional aspects, the text has centering orientation interms of the placement of text elements. In the text, the critical aspects are sized bigger and centered. The critical aspects of the content are visualized by two visual images in the center of the text. The second drawing demonstrates the most critical aspect of the content which is consumption of energy in the transport of the particles from outside of the cell to inner parts. To make this aspect discernible, the participant employed two strategies. The first is centralizing the semiotic resource (drawing) and the second is arranging the size of this meaning unit bigger that other meaning units which can be considered as less critical. For degree of framing, different parts of texts are related by lined zones. When the participant is asked in the interview about why he chooses such a text structure, the response in in the following.

Hasan: *I think that this is the most important thing in the subject of "active transport" since this type of transport requires energy and others do not. If I foreground this aspect into the focus, students will realize more and won't overlook.*

The heading is put in a colored zone and this strategy makes the heading more attractive than the other writings in the text. Relative sizing is successfully used to demonstrate the criticalness hierarchy in this text. For example, visual image in the component 12 is bigger than the visual images in the component 6 since the former involves more critical knowledge than the latter does. This multimodal text can be considered as meaningful since the paradigmatic choices for demonstrating the ideational meaning involves conscious mode choices and the syntagmatic choices to compose text structure is done according to VTL. The participant seems to develop text design competency when it is compared with the situation before the intervention.

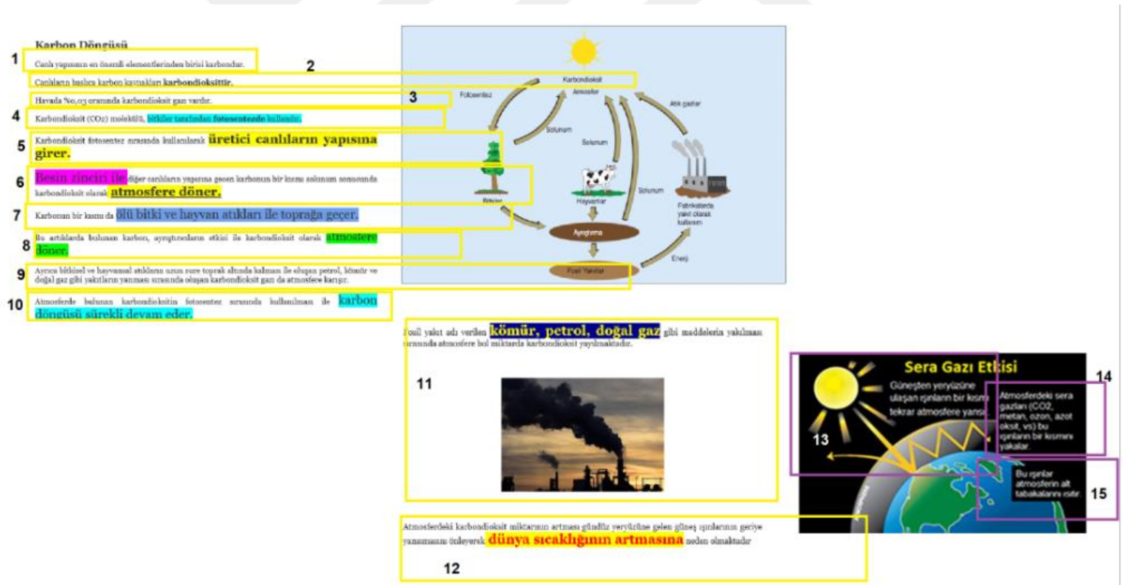

Figure 4.45 Hasan's Text designed in the third iteration of HLT2

The text in Figure 4.45 is about the subject of "Carbon Cycle". The text is designed after the peer evaluation phase where participants evaluated and gave feedbacks to the previous designs. The cross-sematic mapping of DRAs shows that yields that the text has 15 component two of which (1 and 4) are demonstrated completely through language mode. The multimodal components completely include language mode and visual imagery mode since the content does not include mathematical meaning relationships among concepts or entities. The dominant ISMs are intersemiotic complementarity and semiotic metaphor. For example, in component 6 the participants in "food chain" is demonstrated with iconic visual images (intersemiotic complementarity) and the process is metaphorically demonstrated by arrows that are like rotating to represent cyclic rotation. These linguistic and visual imagery semiotic resources help to contextualize meaning of participants taking part in the process, and the meaning of both process (nature of process) and how it takes place (circumstance as cyclic). Since the language mode and visual imagery mode bring typological and topological meaning together, in the multimodal components, the mixed mode semiosis occurs. The frequency of creating ideational variation is relatively low with the Text 3. The variation is observed in only processes. For example, the process of reflection included in Component 8 is demonstrated with both the centering visual image and the black colored visual image. Regarding the paradigmatic choices to represent the content, the participant tried to employ multiple modes to demonstrate the transitivity system elements.

When the compositional aspects of the text are evaluated, it can be seen the placement of text element is centering oriented with poor locating. The cyclic process of carbon is foregrounded with participants, processes, and the circumstances. The degree of framing elements includes colored zones. Additionally, the participant created colored zones for the writings that he considered as important. For the heading, the font size is made bigger than other writings, but with same color. Parallel to foregrounding the critical aspects in the text, relative sizing is done. For example, the blue colored cyclic representation is made bigger than the picture displaying factory chimneys. In sum, the text can be considered as a meaningful since the degree of contextualization of meaning by the use of modes which involve topological and typological meaning is high, and since the strategies drawing on VTL are used in the text composition. However, the text composition can be arranged in way that relate all the parts in a coherent way. The existence of poor locating and unrelated parts due to distance can lead to “split effect” (Herrlingher, 2018) which may lead to distraction in understanding the text content.

2. Overall Progress of Hasan

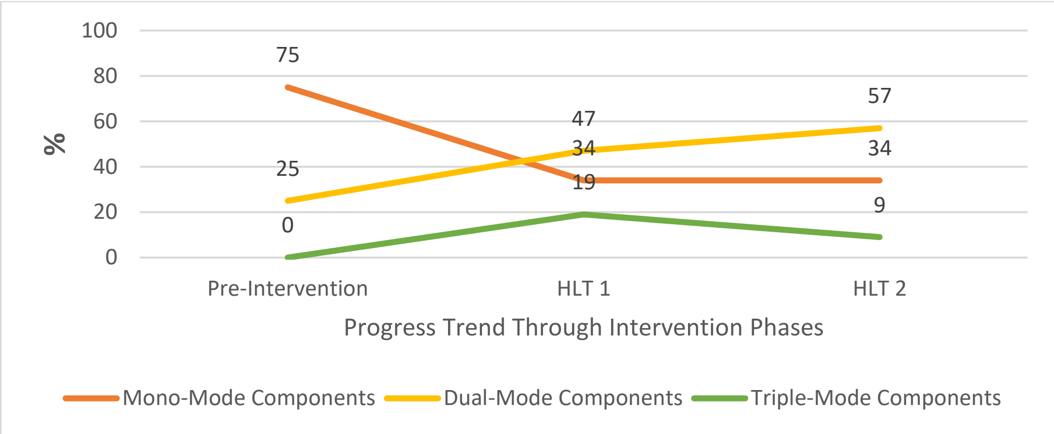

Figure 4.46 The developmental trends for mode levels in the progress of the intervention

In Figure 4.46 above, the percentages of mode levels in Hasan’s texts are presented in each phase of the implementation. The changes in mode levels are demonstrated. In the awareness phase (problem determination), 75 % of components were presented as mono-mode level. In HLT1, 34 % of components were presented in two-mode. In HLT2 34% of components were presented in mono-mode. As can be seen, the number of mono-mode level components had been decreased in the progress of the implementation. The sharpest decrease occurred at the end of the HLT1. This sharp decrease was expected since the HLT1 focused on designing meaningful multimodal representations.

When we look at the changes in the frequencies of dual-modelevel components, we see an increase. In the awareness phase, the percentage of dual-modelevel components was 25%. This percentage increases to 47 % at the end of the HLT1. It is 57 % at the end of HLT2. As expected, the sharpest increase is in the HLT1. This means that the number of multimodal representations increased in the designed didactic science texts. The percentage of triple-modecomponents was zero percent in the awareness phase, 19 % in the HLT1, and 9 % in HLT 2. In the triple-mode components, language, visual imagery, and mathematical modes are used together to demonstrate at least one element in a component. The decrease of triple-mode components is seen expected since the content does not contain mathematical relations. This situation shows the conscious use of mode in text design. There observed an overall increase in the mode-level in the components. This means that participants used more than one mode to demonstrate content and increased the number of multimodal representations.

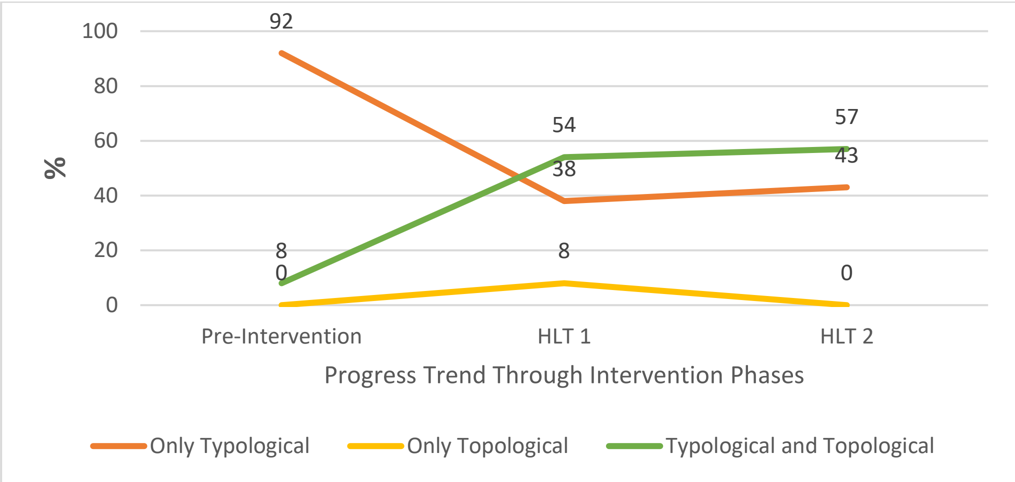

Figure 4.47 The developmental trends for use of meaning types in progress of the intervention

Figure 4.47 demonstrates the developmental trend in the meaning types in used modes in the components. For typological meaning, in the awareness phase, 92 % of components included representation that demonstrate only typological meaning. In the HLT1, the percentage of components including only typological meaning decreased to 38%. In HLT2, the percentage is 43 %. In the progress of the implementation, the percentage of components having only typological meaning is decreased and the sharpest decrease was in the HLT1.

The percentage of components including only topological meaning was zero in awareness phase, 8 % in the HLT1, and 0 % in the HLT2. The percentage of components representing the content by use of modes that include topological and typological meaning had been increased in the progress of implementation. The percentage of components involving typological and topological meaning together was 8 % in awareness step, 54 % in HLT1, and 57 % in HLT2. This implies that the number of components where the meaning is contextualized and expanded through the progress of implementation.

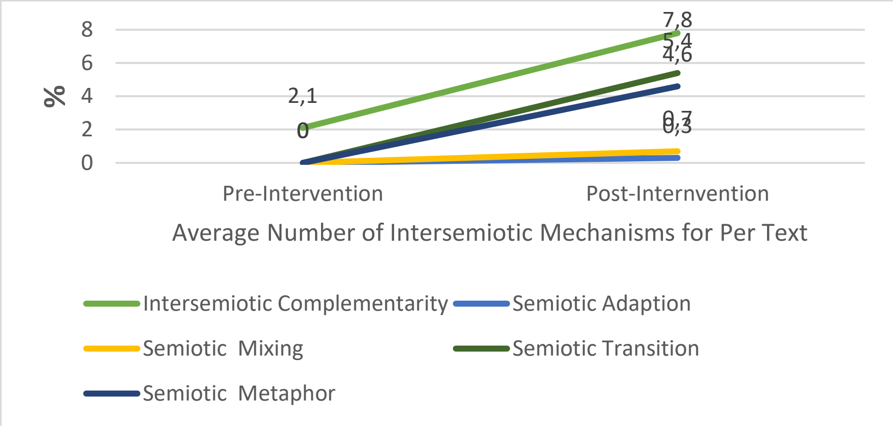

Figure 4.48 The developmental trends for ISMs per text in progress of the intervention

Figure 4.48 demonstrates the average number of constructed ISMs in the multimodal representations. The average number per text demonstrated for pre-intervention and post-intervention that includes the average of all the texts designed during intervention by the participant. As can be seen in the chart, the variety and use of frequency has increased parallel to the increase in the mode level. The critical point here is that the increase for all ISM types demonstrate that participants constructed different types of intersemiotic mechanisms to extend and contextualize meaning. This aspect can be considered as one guarantee of conscious design of multimodal ensembles in texts.

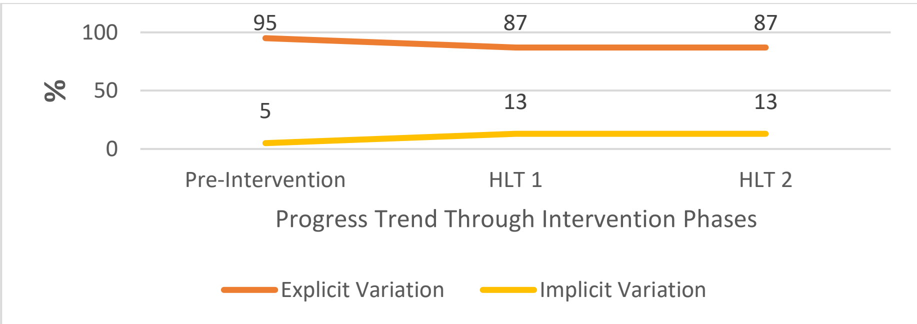

Figure 4.49 The developmental trends for ideational variation in progress of the intervention

The creation of ideational variation around the aspects of the content is also analyzed at component level. In the progress of the intervention, there observed increase in the number of components where explicit variation is created and decrease in the number of the components where implicit variation is created (see Figure 4.49). For the implicit variation, the percentage of components was 95 % in the awareness phase, 87 % in the HLT1, and 87 % in the HLT 2. In parallel, the percentages for explicit variation was 5 % in the awareness phase, 13 % in the HLT1, and 13 % in the HLT 2.

Table 4.22 Observed text composition aspects in Hasan's texts

		Placement of Text Elements			**Foregrounding / Backgrounding**		**Degree of Framing/ Relation**			**Heading/ Subheading**		**Relative Size**
Phase	Text	L/R	R/L	Centering	Critical	Peripheral	Line Zones	Colored Zones	Arrow	Font Size	Font Color	YES NO
Awareness	1	X								X	X	
	2	X								X	X	
	3	X					X	X		X		
HLT1	1			X			X		X	X	X	
	2	X					X	X	X			X
	1	X					X	X				X
	2	X							X			
HLT2	1			X			X	X	X	X	X	X
	2			X	X	X	X		X	X	X	X
	3			X	X	X			X	X	X	X
	4			X	X	X		X		X		X

Table 4.22 demonstrates the observed text composition features of all the texts designed by Hasan in all phases of the study. When the texts of the awareness phase are analyzed, it is seen that all three texts are left/right oriented in terms of placement of texts elements. Foregrounding/backgrounding and relative sizing are not observed. Only textual features observed are the strategy for heading/subheading sizing and use of different colors of for writings. When the texts designed in HLT1 are analyzed, there observed slight increase in the use of compositional features. Three of four texts are left/right oriented and one of them is centering oriented in terms of placement of texts elements. Like awareness phase, this phase does not contain foregrounding/backgrounding aspects which means that the criticalness hierarchy is not constructed in the texts. Two of four texts include lined zones and three of four texts include colored zoned for relation different parts of the texts. Interestingly, only one texts include font sizing and coloring for heading. Furthermore, two of four texts include relative sizing. However, in these texts, relative sizing is done randomly since the texts do not involve criticalness hierarchy. In HLT2, the texts demonstrates more fine-grained compositional features. All three texts are centering oriented. Two of three texts have foregrounding and backgrounding aspects. This refers that, those two texts display the criticalness hierarchy. The table shows that most of the texts involve heading/subheading and relative sizing aspects. The developmental trend in compositional aspects (textual meaning) can be seen in the aimed progress of the intervention.

b. Ebru's Progress

1. Ebru's Texts

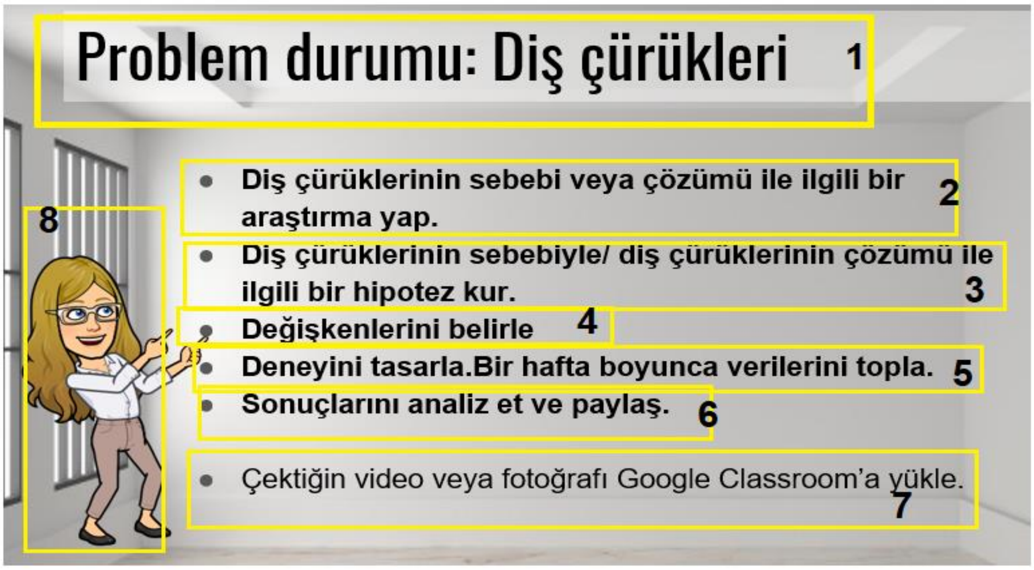

Figure 4.50 Ebru's text designed in the awareness phase

The cross-semantic mapping of DRAs yields that, the text in Figure 4.50 has totally 8 components. The subject of the text is "Tooth Decays". Metafunctional orginizetion of scientific knowledge in each component is demonstrated by mono-mode representation in language mode except component eigtht. The component 8 includes a decorative iconic picture where a woman points out the subject and attract attentions on the information pieces. The text is totally monomodal regarding presentation of information. All transitivity system elements are represented with written language mode and component 8 includes only visual imagery mode. Therefore, there is not any ISM constructed. The knowledge is presented with the semiotic resources and modes which involve only typological meaning. Therefore, the ideational meaning is not contextualized and extended. As such, mixed-mode semiosis is not observed. Furthermore, the ideational variation is implicit in all components. This text is assumed as having low meaning making potential and having limited number of semiotic resources and modes regarding kinds. Therefore, it is also assumed that it can provide limited resources for students to produce creative internalized and externalized learning products.

In terms of compositional aspects and text structure, placement of text elements is left/right placement. The foregrounding and backgrounding of aspects according to criticalness hierarchy and degree of framing elements are not observed. The compositional aspects that help to be more meaningful are font sizing of the heading. What is more the different knowledge parts of the text are separated by use of different coloring in the clauses. There is no relative sizing in the text except the picture. The compositional aspects of the text is low to support meaning making of the content.

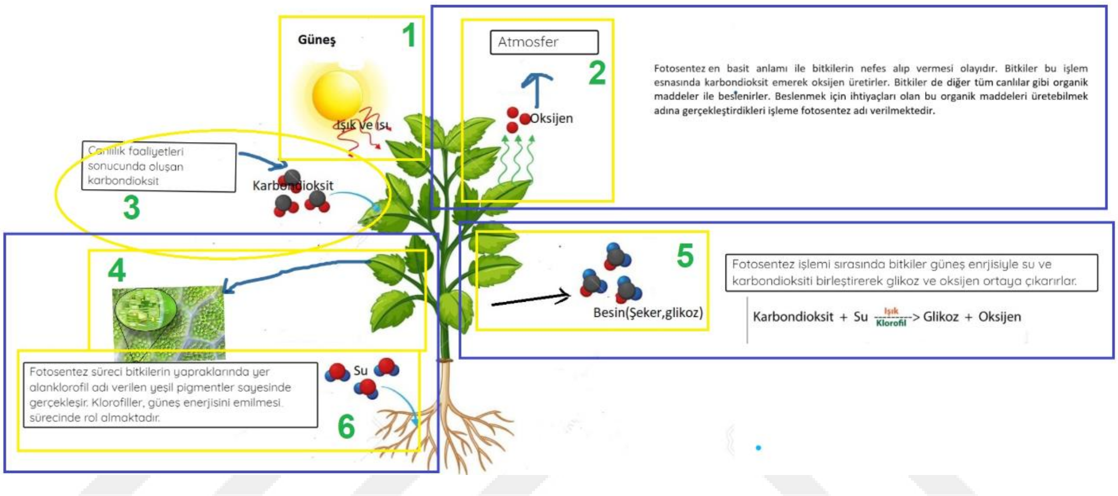

Figure 4.51 Ebru's text designed in the HLT1

The cross-semantic mapping of DRAs yields that the text in Figure 4.51 has totally 8 components. The subject of the text is photosynthesis. There are totally three components, which are represented with mono-mode level representations. Five components are represented in dual-modelevel. The text includes a big iconic image of a plant with all parts visible. Other knowledge parts are located around the this centered visual image. This made two things easier for the designer. First, relating the parts becomes easier for both the designer and reader, and second, the use of semiotic resources becomes economic. Various ISMs are constructed to contextualize meaning. For example, in component 2, the participants are represented with language mode and image mode. This component is a good example of semiotic mixing intersemiotic mechanism where different modes complement each other to create a clause-level meaning unit. Process in this component is represented with arrows, which stands for the process of “emitting”. Here the meaning of participants is contextualized since both language mode (typololgical meaning) and visual mode (topological meaning) is used. Nonetheless, meaning of processes is not contextualized because the act of emitting is only demonstrated with a visual image (topological meaning). Component 8 includes language mode and mathematical formula. Through the semiotic transition ISM, reactants in photosynthesis and mathematical relation between them is formulized. Since both modes involve here only meaning by kind (typological meaning), there is no contextualization of meaning although two modes are used. Therefore, mixed-mode semiosis is not observed. Using multimodal representations (including visual imagery), meanings in components are mostly demonstrated by typological and topological meaning. The text can be considered satisfactory in terms of paradigmatic choices to demonstrate the ideational meaning of the content.

Regarding the syntagmatic dimensions, the compositional aspect of the text includes following features. The text has centering oriented regarding placement of text elements. The foregrounding and backgrounding of aspects according to criticalness hierarchy are observed. Regarding degree of framing, no textual feature is observed. The participant did neither use lined zones nor colored zones. There was font sizing but no coloring for heading and subheading. In the text, the relative sizing of the text parts observed. The most discernible element of the text is the plant with visible parts. In sum, the text can be considered as rich in terms of mode level, semiotic resources and constructed intersemiotic mechanism types. However, the compositional aspects of texts seem having satisfactory quality to demonstrate the critical aspects which students need to focus on more and need to be aware of more. The variation strategy in text composition is not observed.

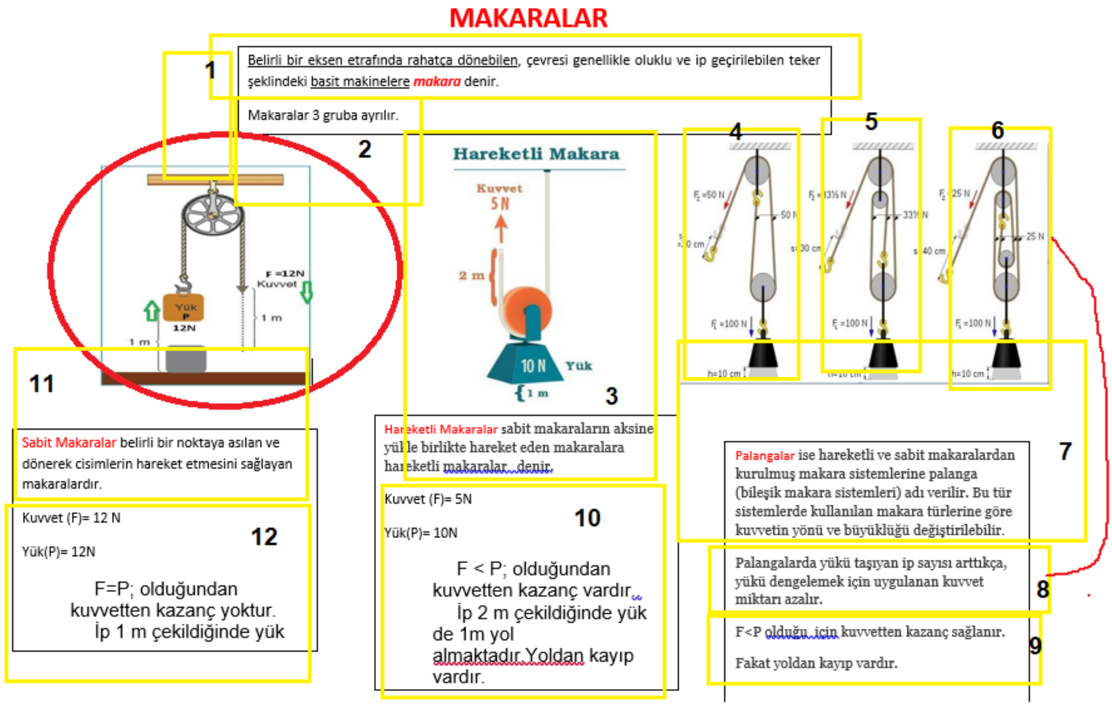

Figure 4.52 Ebru's text designed in the first iteration of HLT2

The text Figure 4.52 has 12 components. The subject of the text is "Pulleys". Only one component has all elements demonstrated by mono-mode. The text is a well combination of components that have three modes. For example, in Component 3, language mode, visual imagery mode, and mathematical mode are use to demonstrate how the moving pulley works with its mathematical principles. Participants (pulley and load) is demonstrated with language mode and visual imagery mode and these two modes co-operate in intersemiotic complementarity mechanism. The meaning relationship or type of process is mathematical; therefore, the process is demonstrated by language mode, visual imagery mode (arrow), and mathematical mode (the case of being heavier). Here, since the mathematical formula includes amount (meaning by degree or topological meaning) and symbolism (meaning by kind or typological meaning), it contributes to contextualization of meaning two-fold. In general, other components of the text have similar semiotic resources and modes in similar intersemiotic mechanism. Components 8 has a distinctive feature where semiotic adaption used for demonstrating processes and circumstance in DRAs in the collaboration of language mode and visual imagery mode. The value described in the language mode is given in another mode. The number of ropes in a pulley block is demonstrated in another component in visual imagery mode and resultant force is demonstrated by mathematical calculation on the pulley block. In components 4, 5, and 6 visual imagery mode and mathematical modes are constructed meaning units without use of language mode. Mathematical symbolism and visual images demonstrate participants, which are contextualized. Arrows and formulas demonstrate the processes and circumstances in semiotic transition ISM. This mechanism enables readers to learn the disciplinary ways of representing of a real-world phenomenon, which is depicted by visual imagery mode or language mode. Here the formula and math symbolism involve typological meaning and visual images involves topological meaning. Therefore, the meaning is contextualized in representing the scientific knowledge. This text also a good instance where explicit variations take place. The common explicit variation for participants is giving different types of pulleys and pulley blocks. By this way, students can experience contrasting options of the concept pulley. Furthermore, different instances of processes and circumstance are given with calculations through mathematical formulas and visual images. This helps to see how the processes take place in different instances such as the number of ropes, load with different weight, or the direction the force. In the interview, the main strategy in designing of this text is asked to the participant. The response is given below.

> ***Ebru:*** *when I design this text, I precisely analyzed the content. Afterwards, I think that if I choose the best modes to demonstrate the content, the text can become more meaningful. For example, I try to use mathematical formula on the images, because it is easier to relate the process demonstrated by visual image and the formula. Students can see what is going on in the formula visually… second thing I do is putting theses mode into the texts in an aim of generating coherent text structure where students can relate parts of texts easily.*

When it is asked to the participant about why she put the pulley pictures in the center of the text and in bigger size and response is given in following.

> ***Ebru:*** *I thought that the most important part of the content is pulleys and pulley types. As such, students firstly need to recognize the physical structure of a pulley and pulley types. Then it becomes easier to give further explanations.*

Regarding compositional aspects, the text has centering orientation in terms of the placement of text elements. In the text, the critical aspects are sized bigger and centered. Two drawing in the center of the text visualizes the critical aspects of the content. To make the physical properties of a pulley more discernible, the participant employed two strategies. The first is centralizing the semiotic resource (drawing) and the second is arranging the size of this meaning unit bigger that other meaning units which can be considered as less critical. For degree of framing, different parts of texts are related by lined zones. Bigger size and colored letters demonstrate the heading. Relative sizing is successfully used to demonstrate the criticalness hierarchy in this text. This multimodal text can be considered as meaningful since the paradigmatic choices for demonstrating the ideational meaning involves conscious mode choices and the syntagmatic choices to compose text structure is done according to VTL. The participant seems to develop text design competency when it is compared with the situation before the intervention.

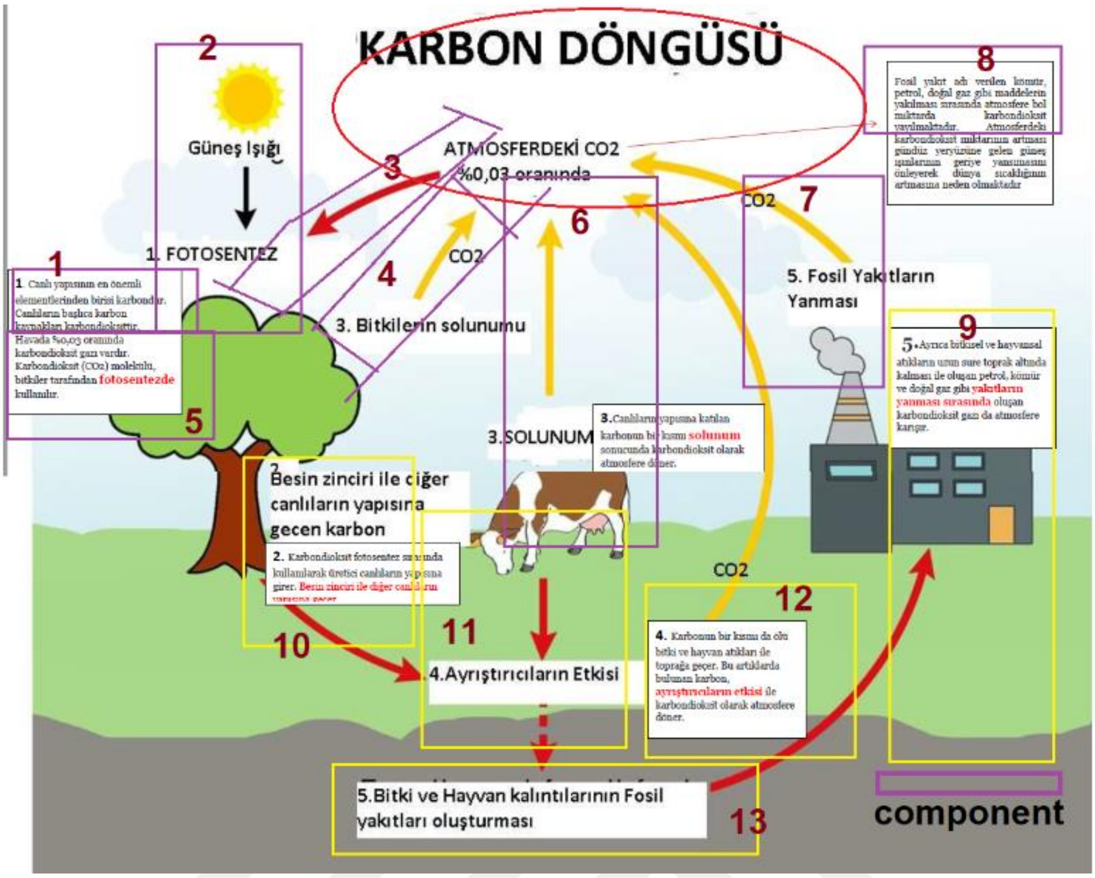

Figure 4.53 Ebru's text designed in the third iteration of HLT2

The text in Figure 4.53 is about the subject of "Carbon Cycle". The text is designed after the peer evaluation phase where participants evaluated and gave feedbacks to the previous designs. The text has 13 component two of which (1 and 13) are demonstrated completely with language mode. The multimodal components completely involve language mode and visual imagery mode since the content does not include mathematical meaning relationships among concepts or entities. The dominant ISMs are intersemiotic complementarity and semiotic metaphor. For example, component 9 includes semiotic metaphor for processes, and intersemiotic complementarity for participants and circumstance. The participants and circumstances are visualized with exemplary iconic representations and the process is demonstrated represented with language mode and the metaphoric visual representation where arrow corresponds to process of "incoming". The text includes many representations of this kind of metaphoric process demonstrated by arrows that also shows the circumstance as cyclic. The text is rich of semiotic resources including colors since it is a cartoonish drawing of a real event taking place in the nature. The ample and conscious use of modes of language mode and visual imagery mode brings typological and topological meaning together, in the multimodal components, the mixed mode semiosis occurs. The frequency of creating ideational variation is relatively low with the Text 3. For example, other kind of living bodies would be given. The ideational variation is observed mostly for processes. Regarding the paradigmatic choices, the text seems satisfactory in representing the ideational meaning.

When the compositional aspects of the text are considered, it can be seen the placement of text element is centering oriented. The cyclic process of carbon is foregrounded with participants, processes, and the circumstances. The degree of framing elements include both lined and colored zones. For the heading the font size is made bigger than other writings, but with same color. Parallel to foregrounding the critical aspects in the text, relative sizing is done. The information in the boxes is designed smaller than the elements of the cycle. The text can be seen to have satisfactory meaning making power since the degree of contextualization of meaning using modes, which involve topological and typological meaning, is high, and since the strategies drawing on VTL are used in the text composition.

2. Overall Progress of Ebru

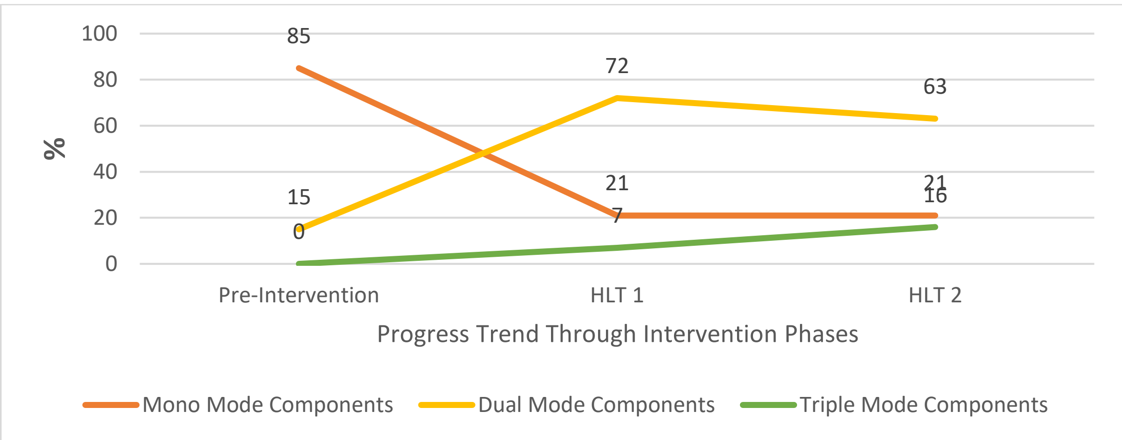

Figure 4.54 The developmental trends for mode levels in the progress of the intervention

In Figure 4.54 above, the percentages of mode levels in Ebru's texts are presented in each phase of the implementation. The changes in mode levels are demonstrated. In the awareness phase (problem determination), 85 % of components were presented as mono-mode level. In HLT1, 21 % of components were presented in two-mode. In HLT2 21 % of components were presented in mono-mode. As can be seen, the number of mono-mode level components had been decreased in the progress of the implementation. The sharpest decrease occurred at the end of the HLT1. This sharp decrease was expected since the HLT1 focused on designing meaningful multimodal representations.

When we look at the changes in the frequencies of dual-mode level components, we see an increase. In the awareness phase, the percentage of dual-modelevel components was 15%. This percentage increases to 72 % at the end of the HLT1. It is 63 % at the end of HLT2. As expected, the sharpest increase is in the HLT1. This means that the number of multimodal representations increased in the designed didactic science texts. The percentage of triple-modecomponents was 0 % in the awareness phase, 7 % in the HLT1, and 16 % in HLT 2. In the triple-mode components, language, visual imagery, and mathematical modes are used together to demonstrate at least one element in a component.

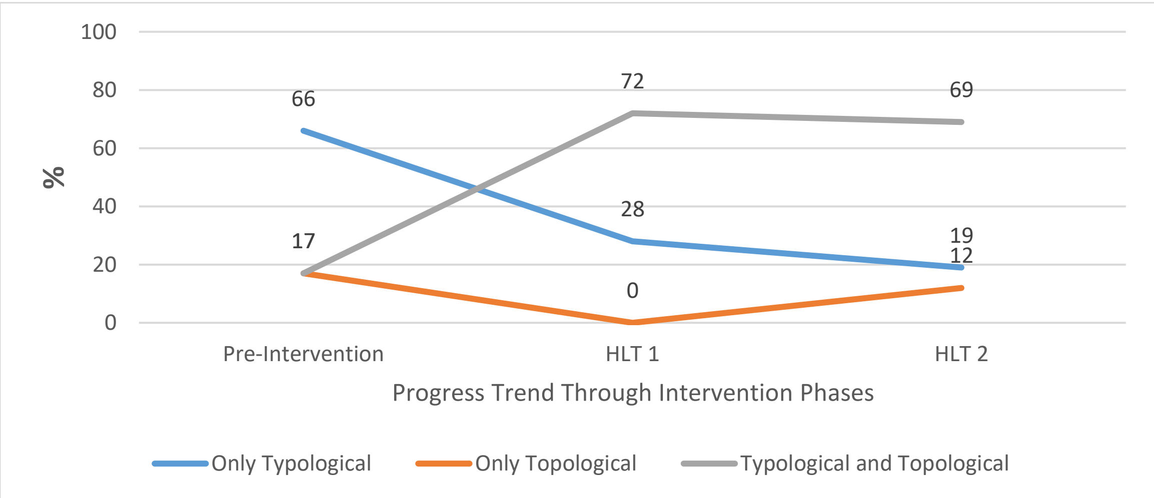

Figure 4.55 The developmental trends for use of meaning types in progress of the intervention

Figure 4.55 demonstrates the developmental trend in the meaning types in used modes in the components. For typological meaning, in the awareness phase, 66 % of components included representation that demonstrate only typological meaning. In the HLT1, the percentage of components including only typological meaning decreased to 28 %. In HLT2, the percentage is 19 %. In the progress of the implementation, the percentage of components having only typological meaning is decreased and the sharpest decrease was in the HLT1. The percentage of components including only topological meaning was; 17 % in awareness phase, 0 % in the HLT1, and 12 % in the HLT2. The percentage of components representing the content by use of modes that include topological and typological meaning had been increased in the progress of implementation. The percentage of components involving typological and topological meaning together was 17 % in awareness step, 72 % in HLT1, and 69 % in HLT2. This means that the number of components where the meaning is contextualized and expanded through the progress of implementation.

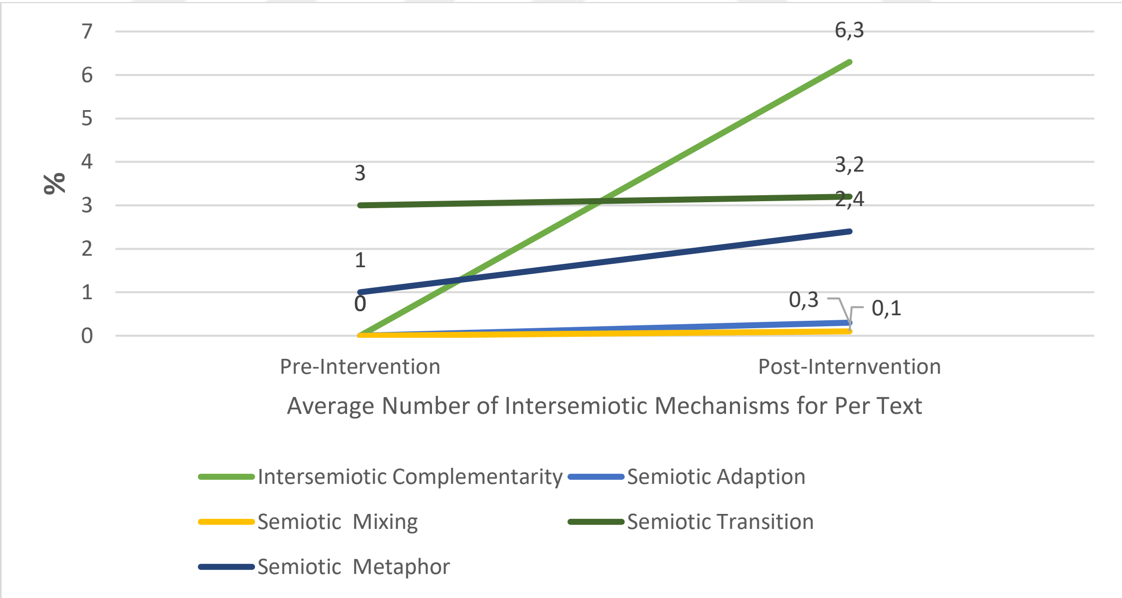

Figure 4.56 The developmental trends for ISM per text in progress of the intervention

Figure 4.56 displays the average number of constructed intersemiotic mechanisms in the multimodal representations. The average number per text demonstrated for pre-intervention and post-intervention that includes the average of all the texts designed during intervention by the participant. As can be seen in the chart, the variety and use of frequency has increased parallel to the increase in the mode level. The increase for all ISM types demonstrate that participants constructed different types of ISMs to extend and contextualize meaning.

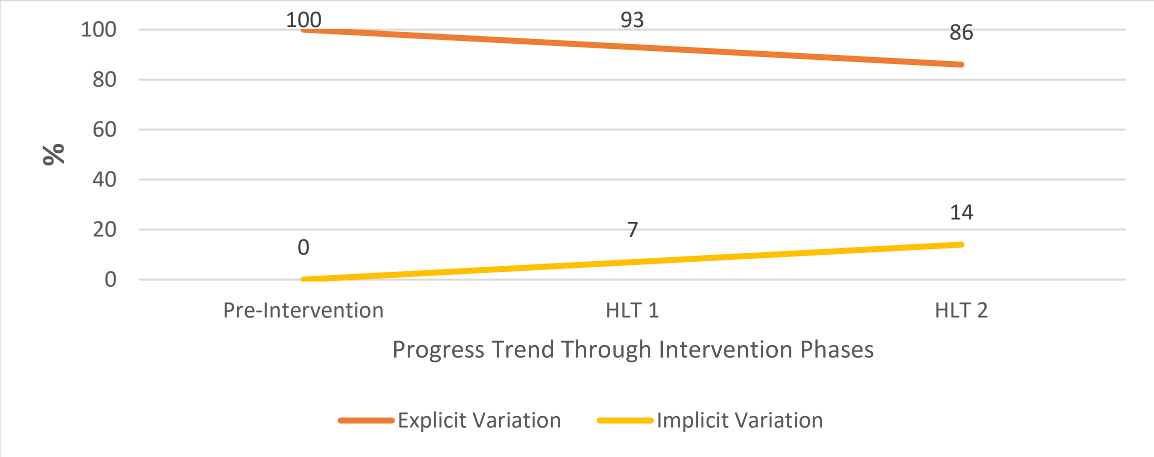

Figure 4.57 The developmental trends for ideational variation in progress of the intervention

The creation of ideational variation around the aspects of the content is also analyzed (see Figure 4.57) at component level. In the progress of the implementation there observed increase in the number of components where explicit variation is created and decrease in the number of the components where implicit variation is created. For the implicit ideational variation, the percentage of components was 100 % in the awareness phase, 93 % in the HLT1, and 86 % in the HLT 2. In parallel, the percentages for explicit variation was 0 % in the awareness phase, 7 % in the HLT1, and 14 % in the HLT 2.

Table 4.23 Observed text composition aspects in Ebru's texts

		Placement of Text Elements			**Foregrounding / Backgrounding**		**Degree of Framing/ Relation**			**Heading/ Subheading**		**Relative Size**
Phase	Text	L/R	R/L	Centering	Critical	Peripheral	Line Zones	Colored Zones	Arrow	Font Size	Font Color	YES NO
Awareness	1	X								X		
	2	X								X	X	X
	3	X						X				X
HLT1	1			X	X	X	X			X	X	X
	2			X	X	X			X	X		X
	3			X			X	X	X	X	X	X
HLT2	1			X	X	X	X	X		X	X	X
	2			X	X	X						
	3			X			X			X	X	X
	4			X	X	X	X	X	X	X	X	X

Table 4.23 above demonstrates the observed text composition features (textual meaning) of all the texts designed by Ebru in all phases of the study. When the texts of the awareness phase are analyzed, it is seen that all three texts are left/right oriented in terms of placement of texts elements. Foregrounding/backgrounding and relative sizing are not observed. Only textual features observed are the strategy for heading/subheading sizing and use of different colors of for writings. When the texts designed in HLT1 are analyzed, there observed sharp increase in the use of compositional features. All texts are centering oriented in terms of placement of

texts elements. Texts designed in this phase contain foregrounding/backgrounding aspects which means that the criticalness hierarchy seem to constructed in the texts. This finding is quite interesting since in this phase of the study training on the compositional aspects of multimodal text had not been given. This change is attributed two things. First is the effort for using semiotic resources economic that generally involves a bigger semiotic resource in the center and relating the other parts with it. The second possibility is the existing text design strategy of the participant engages this strategy. But, according to data (texts and interview) gathered before the intervention, the participant did not seem to have such strategy. In HLT2, all three texts are centering oriented. Two of three texts have foregrounding and backgrounding aspects. This refers that, those two texts display the criticalness hierarchy. The table shows that most of the texts involve heading/subheading and relative sizing aspects. The developmental trends in compositional aspects (textual meaning) can be seen in the objected progress of the intervention.

c. Sude's Progress

1. Sude's Texts

The text in Figure 4.58 was designed by Sude in awareness phase and the text was designed it for actual teaching practice.

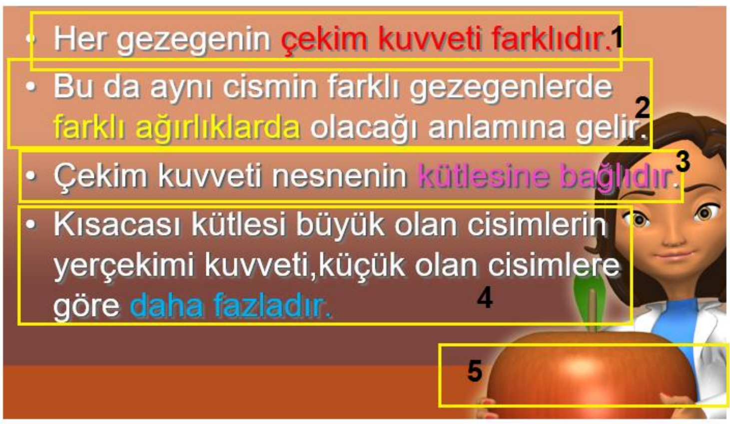

Figure 4.58 Sude's text designed in the awareness phase

The text has totally five components. The subject of the text is “Gravity”. Knowledge in the text is represented with language mode. There is a decorative metaphoric visual image in component 5 where a woman wearing white laboratory coat handling a big apple. This image attributes to the apple falling on Newton’s head and Newton’s law on gravity. The first four components include language mode and totally monomodal. In these components, all transitivity system elements in DRAs are represented with written language mode. Therefore, there is not any ISM constructed for depicting the DRAs. The knowledge is presented with the semiotic resources and modes which involve only typological meaning. Therefore, the ideational meaning is not contextualized or extended. As such, mixed-mode semiosis is not observed for these components. Furthermore, the ideational variation is implicit in all components. This text is assumed as having low meaning making potential and having limited number of semiotic resources and modes regarding kinds. Therefore, it is also assumed that it can provide limited resources for students to produce creative learning outcomes.

In terms of compositional aspects and text structure, placement of text elements is left/right placement. The foregrounding and backgrounding of aspects according to criticalness hierarchy and degree of framing elements are not observed. The compositional aspects that help to be more meaningful is coloring of the letters in the clauses. Critical aspects are highlighted with colored letters. There is no relative sizing in the text except the metaphoric decorative image. The compositional aspect of the text is evaluated to be low to support meaning making of the content.

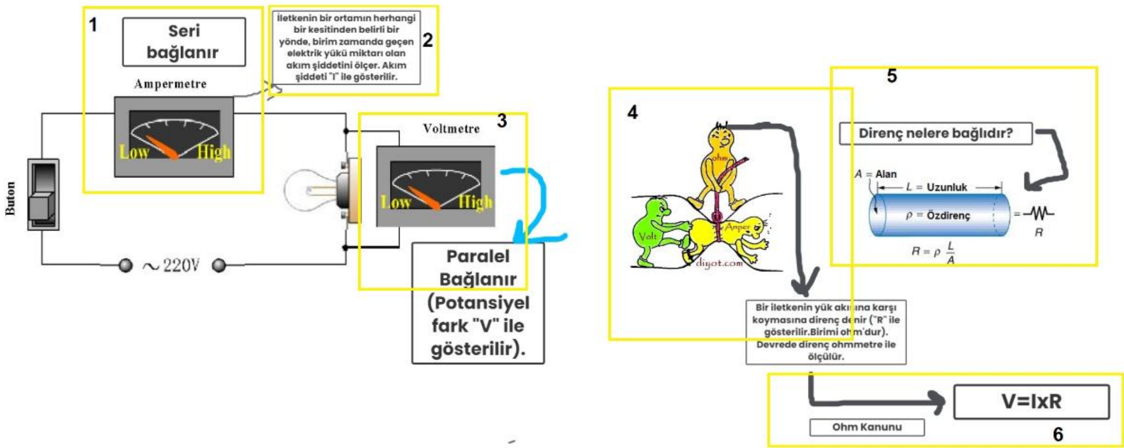

Figure 4.59 Sude's text designed in the HLT1

The text in Figure 4.59 has totally six components. The subject of the text is Ohm's Law. There are totally two components, which are represented with mono-mode level representations (component 2 and 6). Three components are represented in dual-mode level and one component involve triple-modelevel level representation (component 5). For example, in component 1, linguistic mode gives the information that "the ammeter is connected serial in circuit". The visual image demonstrates the ammeter itself, how it is connected (serial) and the act of being connected. Therefore, all the transitivity elements in DRAs are demonstrated by the collaboration of language mode and visual imagery mode in intersemiotic complementarity mechanism. The language mode involves typological meaning while the visual imagery mode involves topological meaning. In this component, these two kinds of meaning are brought together to contextualization of meaning which takes place on intersemiotic complementarity. Since the meaning is extended and contextualized, the mixed-mode semiosis is observed. Component 5 is an exemplary case where three modes are combined to demonstrate the depending on factors of resistance. Process here is demonstrated by language mode (the act of being dependent). Participants are demonstrated with visual imagery mode, visual imagery (the wire) and mathematical symbolism. Here, semiotic transition ISM is constructed since the knowledge is demonstrated with a realistic visual image and disciplinary way of representation. Furthermore, in component 7 the concept of “resistance”, passing of electrons and the circumstance where the process is taking place are represented by three modes. The ISMs are semiotic metaphors where, for example, circumstance of difficulty of passing of electrons is represented with a narrower segment of passing. What is more, the difficulty of passing can be understood from facial expression of the metaphoric human-like representation of electrons. In the text, language, visual imagery, and mathematical modes are collaborated in various intersemiotic mechanisms and through these mechanisms meanings in components are extended. The by the use of multimodal representations, the meanings in components are mostly demonstrated by typological and topological meaning. This means that the mixed-mode semiosis takes place in these components. The creation of mixed-mode semiosis leads to contextualization of meaning which helps the readers of the text can have enhanced meaning making and learning experiences.

The compositional aspect of the text includes following features. The text is left/right oriented regarding placement of text elements. The foregrounding and backgrounding of aspects according to criticalness hierarchy are not observed. Regarding degree of framing, the text parts are separated with only lined. There was not any font sizing and coloring for heading and subheading. In the text, the relative sizing of the text parts observed. However, this relative sizing is not to make the critical aspects discernible since the criticalness hierarchy is not constructed through text composition. In sum, the text can be considered as rich in terms of mode level, semiotic resources and constructed ISM types. However, the compositional aspects of texts seem at low-level compositional features to demonstrate the critical aspects, which students need to focus on more and need to be aware of more. The variation strategy in text composition is not observed.

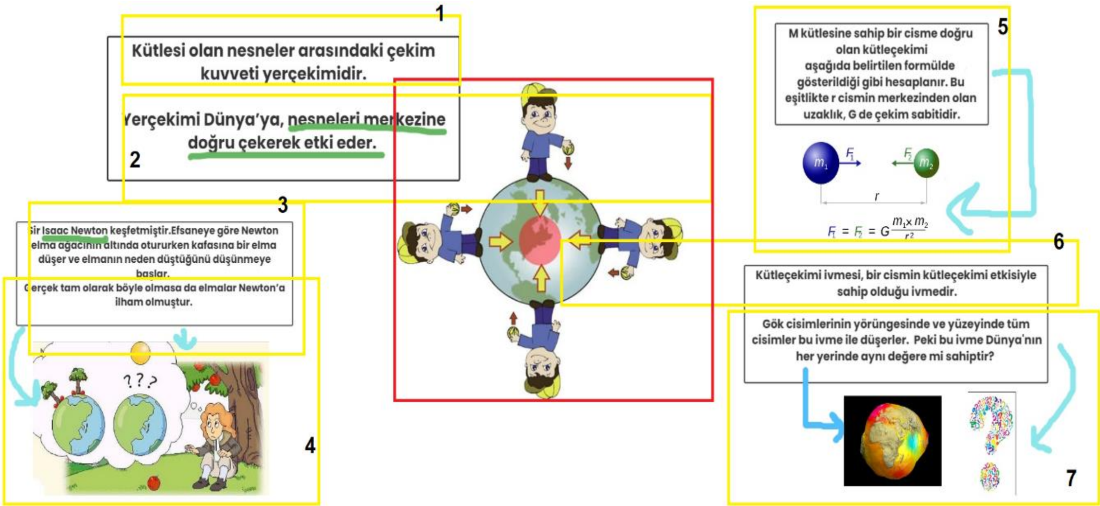

Figure 4.60 Sude's text designed in the first iteration of HLT2

The text in figure 4.60 has 8 components. The subject of the text is "Gravity". The text has the same content with the text designed in the awareness phase. One component is represented with only mono-mode semiotic resources. Remaining five components involve multimodal ensembles. For example, Component 4 involves language mode and visual imagery mode. In this, components the participants, processes and circumstance are also demonstrated by a metaphoric visual image. The story of the falling apple, which is demonstrated in the first text, is given with full scene. The scene includes a man sitting under an apple three and a fallen apple next to the man. Meanwhile, the man is thinking how the causes of the process of falling. The falling of the apple and thinking man visually demonstrate the meaning of content conveyed by language mode. The common ISM used in the text is the intersemiotic complementarity where exemplary instances of any transitivity element is given and semiotic metaphors. The biggest visual in the center of the text demonstrated the meaning "every side of earth has gravity which attracts the objects towards its center". This component is fully demonstrated by visual imagery mode (monomodal) that engages only topological meaning. Component 5 is a good exemplary case where all elements are represented with triple-modemultimodal ensembles. The participants narrated in the linguistic semiotic resources are translated into mathematical symbolism (symbolization) and the process is expressed in mathematical formula. This intersemiotic interaction involves semiotic transition. The participants, processes, and circumstances in DRAs are demonstrated also the visual image showing the heavenly bodies, the act of attracting and the direction. Mathematical symbolism is directly linked with the visual imagery where students can recognize the mathematical principles underling the real-world physical action. The text can be considered as rich in terms of ideational variation. For example, contrasting options of different places in the world is visualized by the centered visual image. The use of this centering visual image also created a semiotic economy whereby the use of less semiotic resources, more meaning and information provided and the relation of different parts of the text became easier. In the interview, the main strategy in designing of this text is asked to the participant. The response is given below.

> ***Sude:*** *When I design the text, I firstly determined concepts and entities taking part in the content. I tried to use both language mode and visual imagery mode to represent them. Then I determined the meaning relationship between them (process types). I tried to use more than one mode to make the content attractive and understandable. I use arrows to relate the different parts of the content (text). Arrows can help and guide student to follow what is going in the text. However, I have also habitual uses. For example, I try to use colors to make the text more attractive.*

Regarding compositional aspects, the text has centering orientation in terms of the placement of text elements. In the text, the critical aspects are represented with a visual image that is sized bigger and located at the center. For degree of framing, different parts of texts are related by lined zones. Relative sizing is successfully used to demonstrate the criticalness hierarchy in this text. For example, visual image in the component 8 (center) is bigger than the visual images in the component 5 since the former involves more critical knowledge than the latter does. This multimodal text can be considered as meaningful since the paradigmatic choices for demonstrating the ideational meaning involves conscious mode choices and the syntagmatic choices to compose text structure is done according to VTL. The participant seems to develop text design competency when it is compared with the situation before the intervention. When the participant is asked in the interview about why he chooses such a text structure, the response in in the following.

> ***Sude:*** *For me, the compositional features of the text can make the content more understandable. Students can discern "which part is more important" in the text if the text foregrounds these parts. As such, this content can be more discernible. In this text, I considered that the most important aspect in the subject of gravity is the attraction of bodies. Therefore, to emphasize this aspect, I foregrounded and centered this aspect with a visual. I also use coloring for the words in the sentences that I think important (most salient strategy before intervention).*

The participant seems to appreciate the importance of the compositional textual structure as meaning making resource in the text. What is more, the strategy she embraces parallel to the what the implementation targets. This text has a specific place regarding other text since the participant designed a text for the same content in the pre-intervention (awareness) phase. If we compare the two texts of same content, the latter text includes more semiotic resources and modes and well-designed text structure. Furthermore, these paradigmatic and syntagmatic choices are informed by conscious pedagogic strategy. This situation can be seen as an effect of the interventions in HLTs.

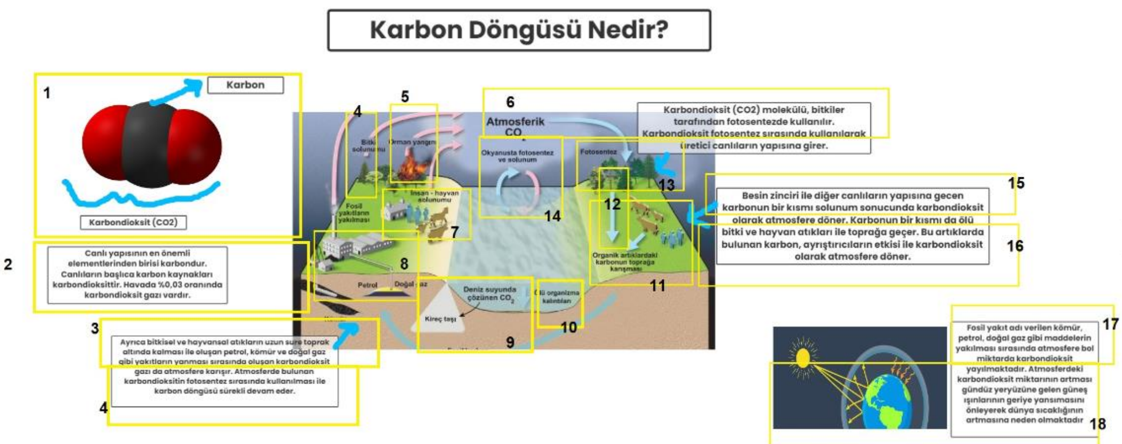

Figure 4.61 Sude's text designed in the second iteration of HLT2

The text in Fgure 4.61 is about the subject of “Carbon Cycle”. The text is designed after the peer evaluation phase where participants evaluated and gave feedbacks to the previous designs. The text has 19 component six of which are demonstrated completely with language mode (monomodal). The multimodal components completely include language mode and visual imagery mode since the content does not include mathematical meaning relationships among concepts or entities. The dominant intersemiotic mechanisms are intersemiotic complementarity and semiotic metaphor.

In the text, the cross-semantic mapping of the participants, circumstances of the process carbon cycle are visualized by a big visual image in the center and information conveyed by language mode is both integrated into this visual and peripherals of the visual. This visual image has realistic drawings that include the factors that emit and consume carbon dioxide. In this respect, the image demonstrates what is going in the content, who is taking part, under which roles and circumstances in a synoptic view. The writings next to this visual image generally gives further explanations and illuminate unclear points. For example, component 3 provides further explanation about the part of carbon cycle happening in subterraneous places. This was due to the visual mode was insufficient since students do not have such an experience in daily life or they are not familiar with such a process.

The metaphoric use of arrows that represent the cyclic process is ample. Furthermore, two visuals are also used next to the centered visual image.

For example, in Component 14, carbon cycle in oceans is demonstrated with iconic visual images (intersemiotic complementarity) and the process is metaphorically demonstrated by arrows that are like rotating to represent cyclic rotation. Such a meaning is demonstrated by collaboration of language mode and visual imagery mode is realized through semiotic mixing ISM. These linguistic and visual imagery semiotic resources help to contextualize meaning of participants taking part in the process, and the meaning of both process (nature of process) and how it takes place (circumstance as cyclic). Since the language mode and visual imagery mode bring typological and topological meaning together, in the multimodal components, the mixed mode semiosis occurs. The ideational variation is observed in only processes. For example, the process of reflection included in component 8 is demonstrated with both the centering visual image and the black colored visual image. Regarding the paradigmatic choices to represent the content, the participant tried to employ multiple modes to demonstrate the transitivity system elements.

When the compositional aspects of the text are evaluated, it can be seen the placement of text element is centering oriented with a good locating. The cyclic process of carbon is foregrounded with participants, processes, and the circumstances. The degree of framing elements includes neither colored nor lined zones. Parallel to foregrounding the critical aspects in the text, relative sizing is done. In sum, the text can be considered as a meaningful since the degree of contextualization of meaning by the use of modes, which involve topological and typological meaning, is high, and since the strategies drawing on VTL are used in the text composition.

2. Overall Progress of Sude

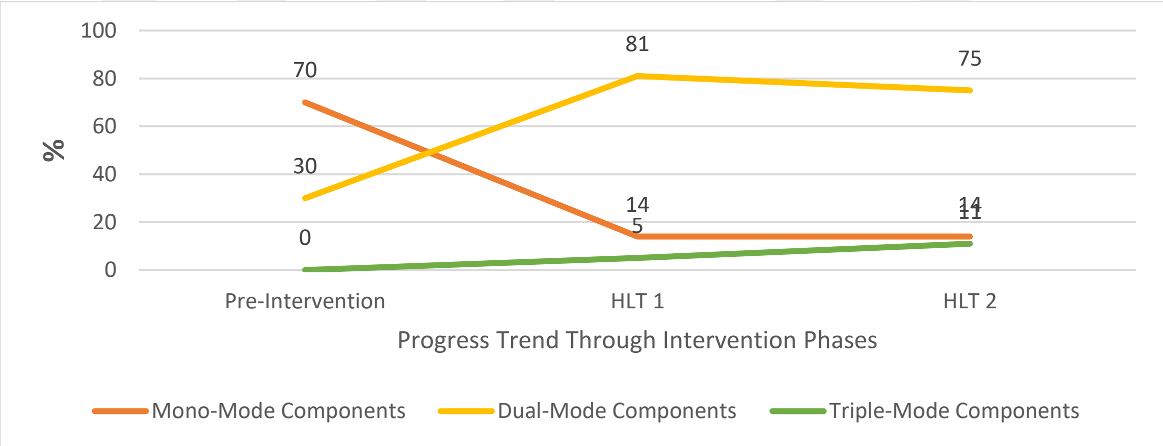

Figure 4.62 The developmental trends for mode levels in the progress of the intervention

In Figure 4.62 above, the percentages of mode levels in Sude's texts are presented in each phase of the implementation. The changes in mode levels are demonstrated. In the awareness phase (problem determination), 70 % of components were presented as mono-mode level. In HLT1, 14 % of components were presented in two-mode. In a comparison to other participant, this participant has texts that have higher mode level in the pre-intervention phase. In HLT2 14 % of components were presented in mono-mode. As can be seen, the number of mono-mode level components had been decreased in the progress of the implementation. The sharpest decrease occurred at the end of the HLT1. This sharp decrease was expected since the HLT1 focused on designing meaningful multimodal representations.

When we look at the changes in the frequencies of dual-modelevel components we see an increase. In the awareness phase, the percentage of dual-modelevel components was 30%. This percentage increases to 81 % at the end of the HLT1. It is 75 % at the end of HLT2. As expected, the sharpest increase is in the HLT1. This means that the number of multimodal representations increased in the designed didactic science texts. The percentage of triple-mode components was 0 % in the awareness phase, 5 % in the HLT1, and 11 % in HLT 2. In the triple-mode components, language, visual imagery, and mathematical modes are used together to demonstrate at least one element in a component. The decrease of triple-mode components is seen expected since the content does not contain mathematical relations. There observed an overall increase in the mode-level in the components. This means that the participant used more than one mode to demonstrate content and increased the number of multimodal representations.

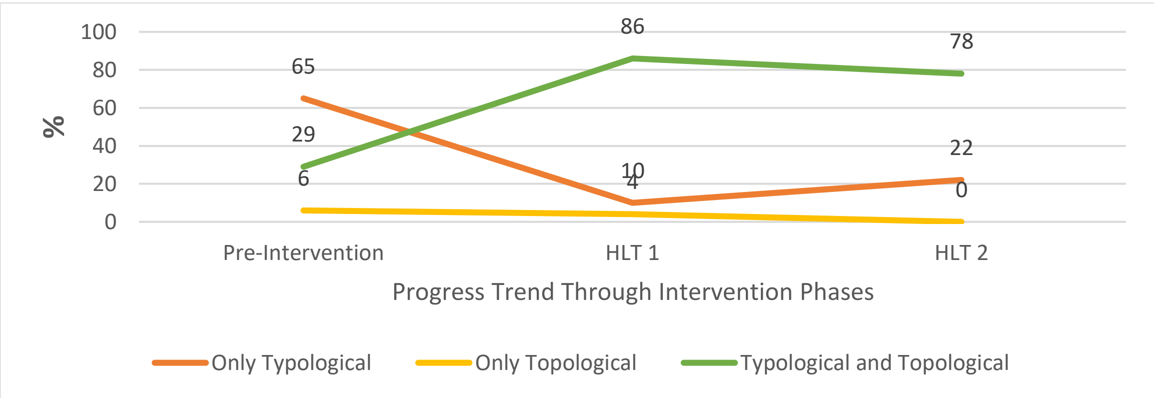

Figure 4.63 The developmental trends for use of meaning types in progress of the intervention

Figure 4.63 demonstrates the developmental trend in the meaning types in used modes in the components. For typological meaning, in the awareness phase, 65 % of components included representation that demonstrate only typological meaning. In the HLT1, the percentage of components including only typological meaning decreased to 10%. In HLT2, the percentage is 22%. In the progress of the implementation, the percentage of components having only typological meaning is decreased and the sharpest decrease was in the HLT1.

The percentage of components including only topological meaning was 6 % in awareness phase, 4 % in the HLT1, and 0 % in the HLT2. The percentage of components representing the content by use of modes that include topological and typological meaning had been increased in the progress of implementation. The percentage of components involving typological and topological meaning together was 29 % in awareness step, 86 % in HLT1, and 78 % in HLT2. This means that the number of components where the meaning is contextualized and expanded through the progress of implementation.

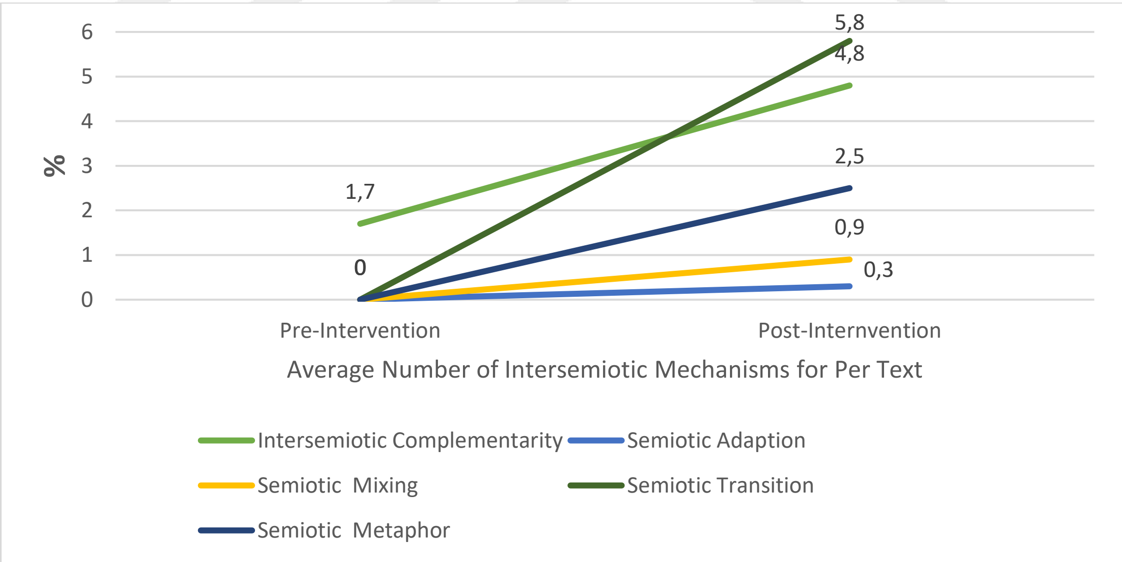

Figure 4.64 The developmental trends for ISM per text in progress of the intervention

Figure 4.64 shows the average number of constructed intersemiotic mechanisms in the multimodal representations. The average number per text demonstrated for pre-intervention and post-intervention that includes the average of all the texts designed during intervention by the participant. As can be seen in the chart, the variety and use of frequency has increased parallel to the increase in the mode level. All ISM types demonstrate that participants constructed different types of intersemiotic mechanisms to extend and contextualize meaning.

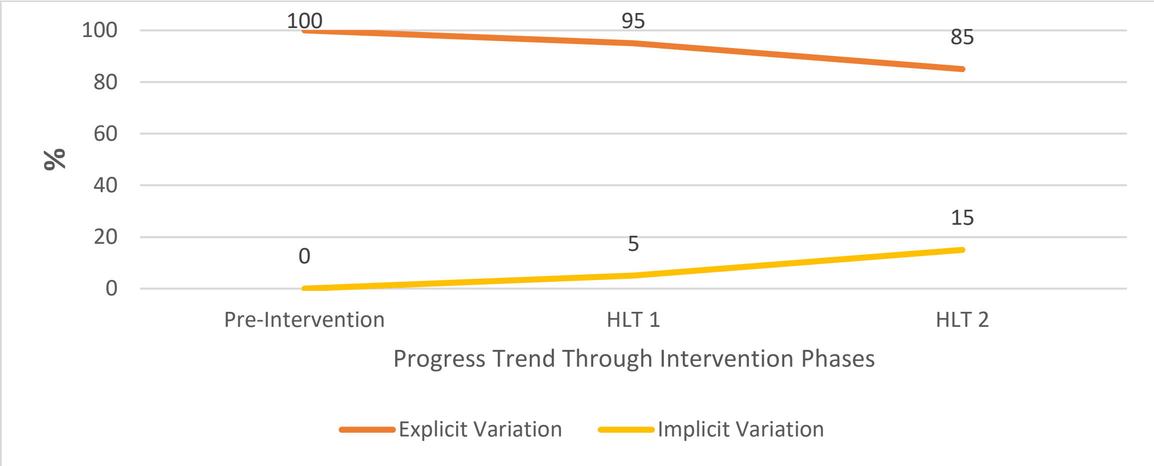

Figure 4.65 The developmental trends for ideational variation in progress of the intervention

The creation of ideational variation around the aspects of the content is also analyzed at component level (see Figure 4.65). In the progress of the intervention, there observed increase in the number of components where explicit variation is created and decrease in the number of the components where implicit variation is created. For the implicit ideational variation, the percentage of components was 100 % in the awareness phase, 95 % in the HLT1, and 85 % in the HLT 2. In parallel, the percentages for explicit variation was 0 % in the awareness phase, 5 % in the HLT1, and 15 % in the HLT 2.

Table 4.24 Observed text composition aspects in Sude's texts

		Placement of Text Elements			Foregrounding / Backgrounding		Degree of Framing/ Relation			Heading/ Subheading		Relative Size
Phase	Text	L/R	R/L	Centering	Critical	Peripheral	Line Zones	Colored Zones	Arrow	Font Size	Font Color	YES NO
Pre-Intervention	1	X						X			X	
	2			X	X	X		X		X	X	X
	3			X	X	X	X			X	X	X
HLT1	1			X	X	X	X		X	X		X
	2	X					X		X	X		
	3	X							X	X	X	
HLT2	1	X					X	X	X	X	X	
	2			X	X	X	X	X				X
	3			X	X	X	X		X	X	X	X
	4			X	X	X			X	X		X

Table 4.24 demonstrates the observed text composition features (textual meaning) of all the texts designed by Sude in all phases of the study. When the texts of the awareness phase are analyzed, it is seen that two of three texts are centered oriented in terms of placement of texts elements and critical aspects are foregrounded. In the HLT1, these finding changes reverse for the left/right orientation and one text demonstrates criticalness hierarchy. Furthermore, use of lined zones and colored zones for the degree of framing, use of font size and font

color for heading/subheading are commonly observed in awareness phase and HLT1. Interestingly, the text orientation and foregrounding/backgrounding aspects changed in HLT1 and even in the first text of the HLT2. This change is from central to left/right placement. Yet, last three texts are centering oriented consistently. This can be evaluated as that the participant was using the centered oriented placement with poor pedagogical justification. The interview data gathered in the awareness phase corroborates this assumption. In the first text (first iteration) of the HLT2 participant was unclear about designing the of multimodal text composition. The further development of the intervention demonstrated its effect on the text composition competency of the participant. When we look at the compositional features of the texts, two three texts demonstrate more fine-grained compositional features. Two of three texts have foregrounding and backgrounding aspects. This refers that, those two texts display the criticalness hierarchy. The table shows that most of the texts involve heading/subheading and relative sizing aspects. The developmental trend in compositional aspects (textual meaning) can be seen in the expected progress of the intervention.

d. Eda's Progress

1. Eda's Texts

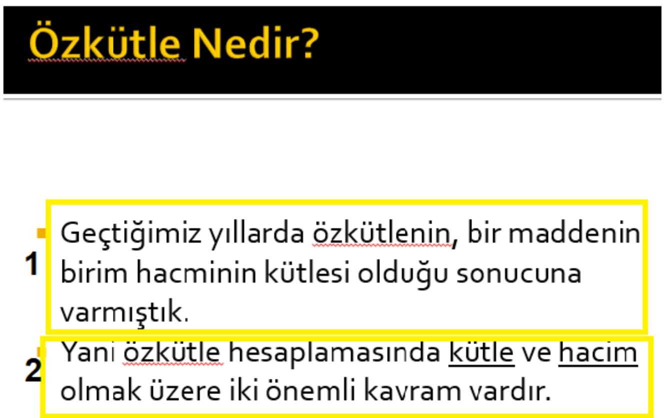

Figure 4.66 Eda's text designed in the awareness phase

The in Figure 4.66 text has totally 2 components. The subject of the text is “Density”. The DRAs in each component is demonstrated by mono-mode representation in language mode. The text is totally monomodal regarding presentation of information. All transitivity system elements are represented with written language mode. Therefore, there is not any ISM constructed. The knowledge is presented with the semiotic resources and modes which involve only typological meaning. Therefore, the ideational meaning is not contextualized and extended. As such, mixed-mode semiosis is not observed. Furthermore, the ideational variation is implicit in all components. This text is assumed as having low meaning making potential and having limited number of semiotic resources and modes regarding kinds. Therefore, it is also assumed that it can provide limited resources for students to produce creative learning outcomes.

In terms of compositional aspects and text structure, placement of text elements is left/right placement. The foregrounding and backgrounding of aspects according to criticalness hierarchy and degree of framing elements are not observed. The compositional aspects that help to be more meaningful are font sizing of the heading. What is more the different knowledge parts of the text are separated by use of different coloring in the clauses. There is no relative sizing in the text except the picture. The compositional aspect of the text is insatisfactory to support meaning making of the content since the discernment of DRAs is relatively difficult.

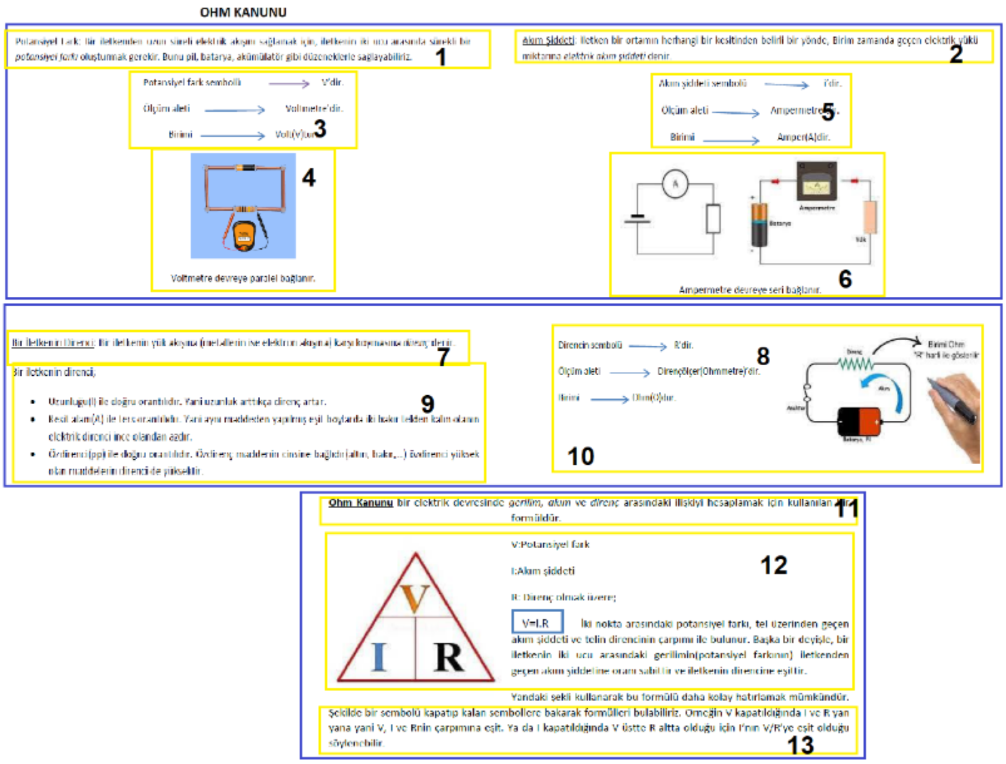

Figure 4.67 Eda's text designed in the HLT1

The text in Figure 4.67 has totally 13 components. The subject of the text is "Ohm's Law". There are totally five components, which are represented with mono-mode level representations. Eight components are represented in dual-modelevel. The participant separated the knowledge parts in the content and created component level meaning units. The text involves language mode, visual imagery mode, and mathematical mode. The monomodal components are dominantly involve language mode. For example, scientific knowledge in the first component is represented with only language mode. Third and fifth components do not include circumstance as a transitivity system element. They include participants in language mode and process of relation in visual imagery mode. There is semiotic mixing ISM through which linguistic elements and visual imagery elements complements each other to create a meaning unit as component. Component 4 is a typical case where all the transitivity system elements are represented with both language mode and visual imagery mode. In intersemiotic complementarity mechanism, the two mode co-operate together to create typological and topological meaning. Consequently, the meaning is contextualized. In component 6, meaning is contextualized in similar to the Component 4. Additionally, the disciplinary representation of the concept of circuit demonstrated. This created an explicit variation for the aspect of circuit where students can experience the realistic description and the disciplinary way of demonstration. In component 12, language mode is complemented with mathematical symbolism and formula in semiotic transition mechanism. The formula synoptically represents the process. Additionally, the placement of symbolized participants “voltage”, “current”, and “resistance” into the iconic image of triangle metaphorically delineates the circumstance of the relationships taking place between these participants or concepts. In this component, three modes complement each other to demonstrate the scientific knowledge. The use of multimodal representations (including visual imagery), meanings in components are mostly demonstrated by typological and topological meaning. The text can be considered satisfactory in terms of paradigmatic choices to demonstrate the ideational meaning of the content.

The compositional aspect of the text includes following features. The text is left/right oriented regarding placement of text elements. The foregrounding and backgrounding of aspects according to criticalness hierarchy are not observed. Regarding degree of framing, no textual features are observed. The participant did use neither lined zones nor colored zones. There was font sizing but no coloring for heading and subheading. In the text, no relative sizing of the text parts is observed. In sum, the text can be considered as rich in terms of mode level, semiotic resources and constructed ISM types. However, the compositional aspects of text do not seem having satisfactory quality to demonstrate the critical aspects which students need to focus on more and need to discern more. The variation strategy in text composition is not observed.

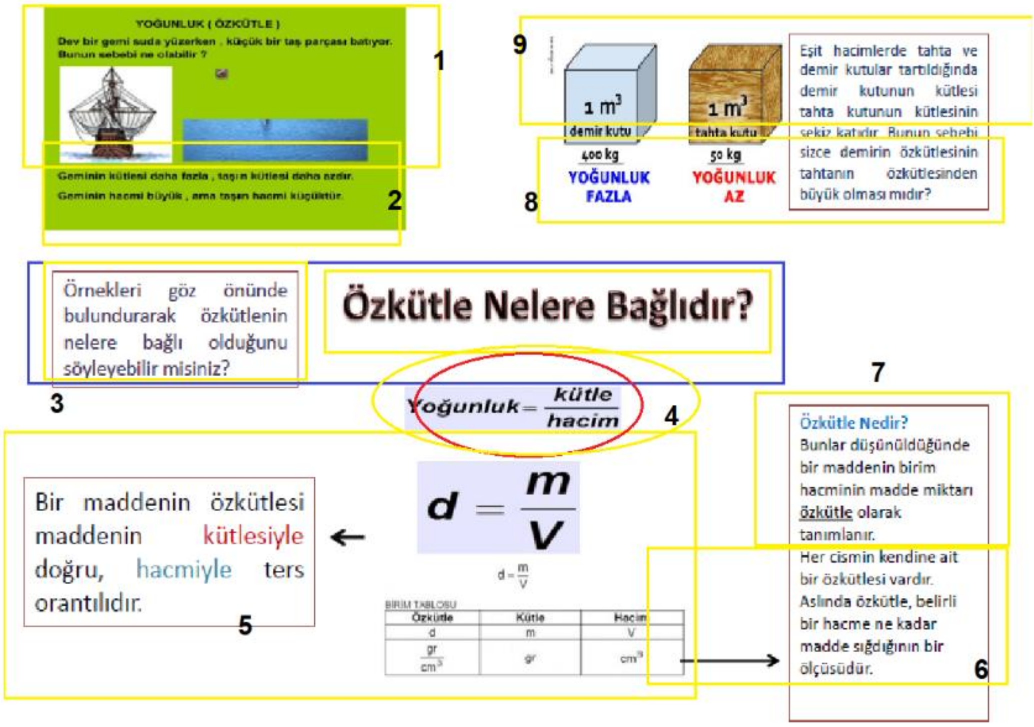

Figure 4.68 Eda’s text designed in the first iteration of HLT2

The text in Figure 4.68 has 9 components. The subject of the text is “Density”. The text has the same content with the text designed in the awareness phase. Components 3, 5, and 7 are represented with only mono-mode semiotic resources. Remaining six components involve dual-modemultimodal ensembles. At the center of the image the critical aspect, which involves depending factors of density, is given with a question in language mode and the factors (mass and volume) with quantitative (mathematical) relations. Around this critical aspect, other meaning units are placed, and the parts are related with arrows. In component 1, the concept of density is explained with real life examples (ship and stone) demonstrated by visual images. The concept is depicted through hanging on the water or sinking. The processes and participants are demonstrated with both language and visual imagery mode while circumstances are demonstrated by only visual image. In this component, explicit ideational variation of different circumstances of density is created. Students can experience two contrasting situations to understand the concept of density better. Such an explicit ideational variation is created in

Component 9 where different cases of being dense are given by language and visual imagery mode. Component 6 is a good example of semiotic adaption intersemiotic mechanism. In this component, the symbolic values of the participants are given in the table. In this component, language mode and the mathematical symbolism are used to demonstrate the symbolic values of participants taking part in the process. In the interview, the main strategy in designing of this text is asked to the participant. The response is given below.

> ***Eda:*** *When I design the text, I firstly determined concepts and entities taking part in the content. Then I try to choose modes that can demonstrate the content best. For example, if the content involves spatial relations between the entities, I try to use a visual image and on that image, I relate the concepts. If there is a mathematical relationship, I use mathematical formula to demonstrate the process synoptically. Furthermore, if I want to concretize an abstract content, I use realistic images with language. I also tried being economical in the use of resources and I do not want to use unnecessary resources or modes.*

Regarding compositional aspects, the text has centering orientation in terms of the placement of text elements. In the text, the critical aspects are represented with a linguistic element and a mathematical formula that is sized bigger and located at the center. For degree of framing, different parts of texts are related by lined and colored zones. Relative sizing is not successfully used to demonstrate the criticalness hierarchy in this text. This multimodal text can be considered as meaningful since the paradigmatic choices for demonstrating the ideational meaning involves conscious mode choices and the syntagmatic choices to compose text structure is done according to VTL. The participant seems to develop text design competency when it is compared with the situation before the intervention. When the participant is asked in the interview about why he chooses such a text structure, the response in in the following.

> ***Eda:*** *I separate the text into smaller units, and I use arrows to relate them. I also employ coloring or shading different units of the text and relate them. In arranging the compositional features of the text, I determine the critical aspect*

of the text, I show it in the center and bigger. Afterwards, I put the less important knowledge parts around this critical part.

The participant also seems to consider the importance of the compositional structure of the text as a meaning making resource. Furthermore, the strategy she embraces parallel to the what the implementation targetted. This text has a specific place regarding other texts since the participant designed a text for the same content in the pre-intervention (awareness) phase. If we compare the two texts of same content, the latter text includes more semiotic resources and modes and well-designed text structure. Furthermore, these paradigmatic and syntagmatic choices are informed by a developed pedagogic strategy. This situation can be seen as an effect of the implementation.

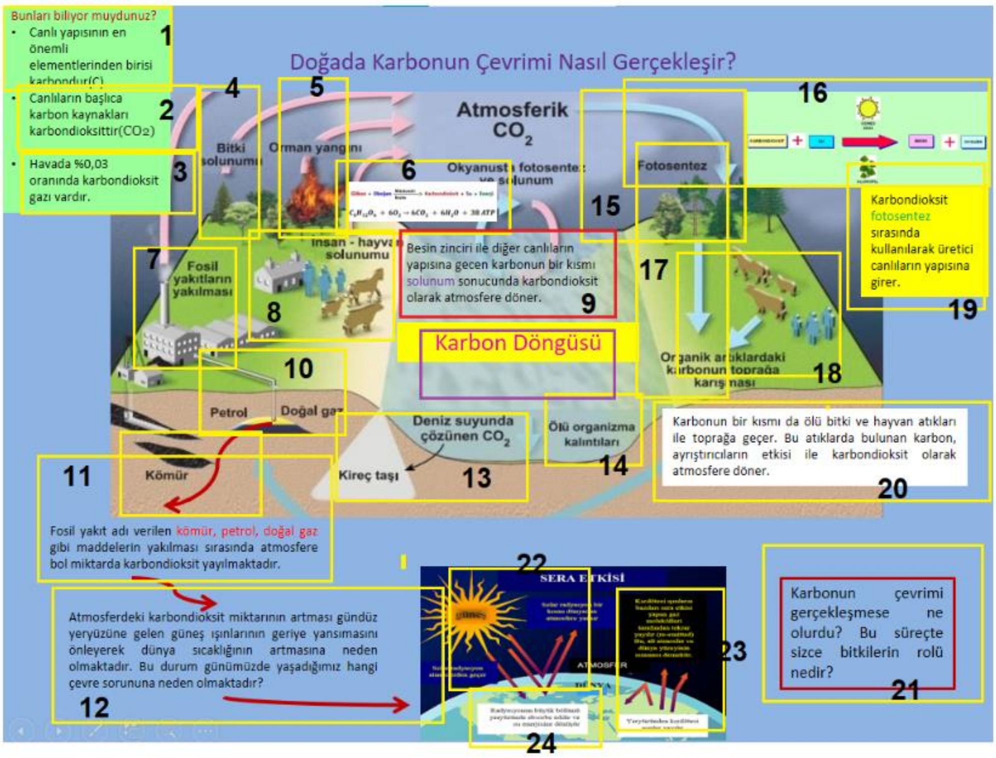

Figure 4.69 Eda’s text designed in the second iteration of HLT2

The subject of th text in Figure 4.69 is “Carbon Cycle”. It is designed after the peer evaluation phase where participants evaluated and gave feedbacks to the previous designs. The text has 23 component seven of which are demonstrated completely with language mode (monomodal). The multimodal components completely include language mode and visual imagery mode since the content does not include mathematical meaning relationships among concepts or entities. The dominant ISMs are intersemiotic complementarity, semiotic mixing, and semiotic metaphor. In the text, the participants, circumstances of the process carbon cycle is visualized by a big visual image in the center and information conveyed by language mode is both integrated into this visual and peripherals of the visual. This visual image has realistic drawings that include the factors that emit and consume carbon dioxide. The image demonstrates what is going in the content, who is taking part, under which roles and circumstances in a synoptic view. The central image is accompanied with knowledge parts mostly in language mode. These parts explain the related segment of the carbon cycle. The heading of the text is put in the center with a yellow colored zone. In the Component 1, engaging daily life facts are given to attract the reader's interest to the content. Most of the components are demonstrated with language mode and visual imagery mode in semiotic mixing intersemiotic mechanism. For example, in Component 7, the act of burning of fossil fuels is demonstrated by a factory and chimney that emits smoke (carbon dioxide). In component 6, the process of burning is demonstrated by two chemical formulas. In the first formula, the participants are demonstrated with language mode while they are given with chemical symbols in the other formula. This component involves semiotic transition mechanism in the collaboration of language and mathematical mode. This component includes explicit ideational variation of the process of burning. In the text, the use of arrows is two-fold. Firstly, they are used to represent the cyclic process of emitting and consuming. These arrows are used in the centered visual image. Secondly, they are used to related different parts of the text. The text has rich paradigmatic resource choices to demonstrate content and diverse intersemiotic mechanism. In the multimodal components, the mixed mode semiosis is common. This means that, through use of various semiotic resources and modes the meaning is extended and contextualized.

When the compositional aspects of the text are evaluated, it can be seen the placement of text element is centering oriented with an exemplary locating. The cyclic process of carbon is foregrounded with participants, processes, and the circumstances. The degree of framing elements includes both colored and lined zones. Parallel to foregrounding the critical aspects in the text, relative sizing is successfully done. This can be understood from the size of the visual demonstrating green house effect. In sum, the text can be considered as a meaningful since the degree of contextualization of meaning by the use of modes, which involve topological and typological meaning, is high, and since the strategies drawing on VTL are used in the text composition.

2. Overall Progress of Eda

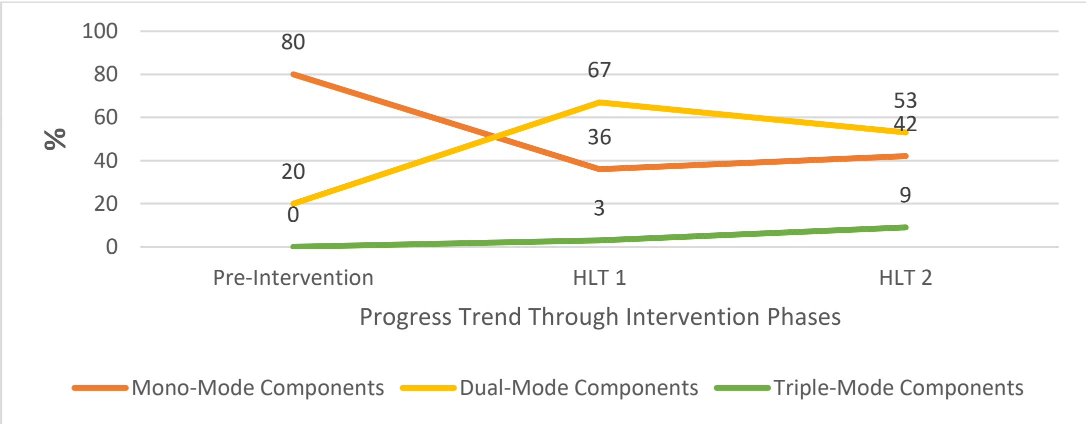

Figure 4.70 The developmental trends for mode levels in the progress of the intervention

In Figure 4.70 above, the percentages of mode levels in Eda's texts are presented in each phase of the intervention. The changes in mode levels are demonstrated. In the awareness phase (problem determination), 80 % of components were presented as mono-mode level. In HLT1, 36 % of components were presented in two-mode. In HLT2 42 % of components were presented in mono-mode. As can be seen, the number of mono-mode level components had been decreased in the progress of the implementation. The sharpest decrease occurred at the end of the HLT1. This sharp decrease was expected since the HLT1 focused on designing meaningful multimodal representations.

When we look at the changes in the frequencies of dual-modelevel components, we see an increase. In the awareness phase, the percentage of dual-mode level components was 20%. This percentage increases to 67 % at the end of the HLT1. It is 53 % at the end of HLT2. As expected, the sharpest increase is in the HLT1. This means that the number of multimodal representations increased in the designed didactic science texts. The percentage of triple-mode components was 0 % in the awareness phase, 7 % in the HLT1, and 16 % in HLT 2. In the triple-mode components, language, visual imagery, and mathematical modes are used together to demonstrate at least one element in a component. The decrease of triple-mode components is seen expected since the content does not contain mathematical relations. This situation shows the conscious use of mode in text design. There observed an overall increase in the mode-level in the components. This means that participants used more than one mode to demonstrate content and increased the number of multimodal representations.

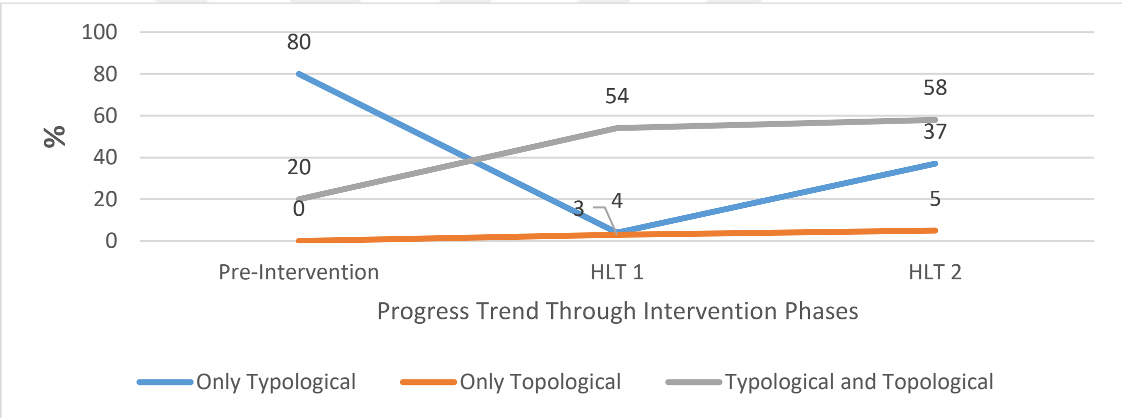

Figure 4.71 The developmental trends for use of meaning types in progress of the intervention

Figure 4.71 shows the developmental trends in the meaning types in used modes in the components. For typological meaning, in the awareness phase, 80 % of components included representation that demonstrate only typological meaning. In the HLT1, the percentage of components including only typological meaning decreased to 4 %. In HLT2, the percentage is 37 %. In the progress of the implementation, the percentage of components having only typological meaning is decreased and the sharpest decrease was in the HLT1. The percentage of components including only topological meaning was 0 % in awareness phase, 3 %

in the HLT1, and 5 % in the HLT2. The percentage of components representing the content by use of modes that include topological and typological meaning had been increased in the progress of implementation. The percentage of components involving typological and topological meaning together was 20 % in awareness step, 54 % in HLT1, and 58 % in HLT2. This means that the number of components where the meaning is contextualized and expanded through the progress of implementation.

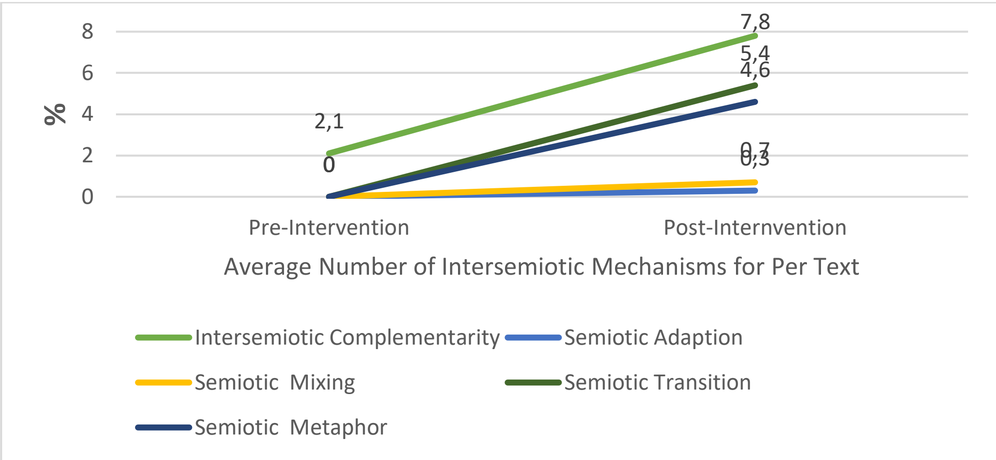

Figure 4.72 The developmental trends for ISM per text in progress of the intervention

Figure 4.72 displays the average number of constructed ISMs in the multimodal representations. The average number per text demonstrated for pre-intervention and post-intervention that includes the average of all the texts designed during intervention by the participant. As can be seen in the chart, the variety and use of frequency has increased parallel to the increase in the mode level. The increase for all ISM types demonstrate that participants constructed different types of intersemiotic mechanisms to extend and contextualize meaning.

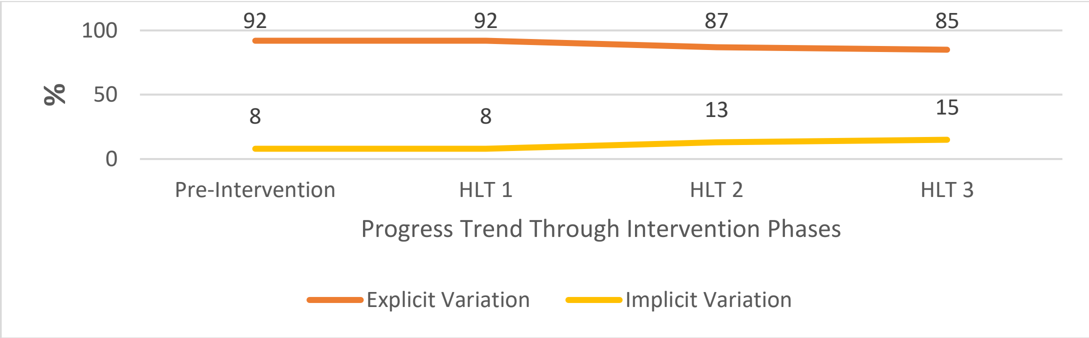

Figure 4.73 The developmental trends for ideational variation in progress of the intervention

The creation of ideational variation around the aspects of the content is also analyzed at component level (see Figure 4.73). In the progress of the intervention there observed increase in the number of components where explicit variation is created and decrease in the number of the components where implicit variation is created. For the implicit ideational variation, the percentage of components was 92 % in the awareness phase, 92 % in the HLT1, and 87 % in the HLT 2. In parallel, the percentages for explicit variation were 8 % in the awareness phase, 8 % in the HLT1, and 13 % in the HLT 2.

Table 4.25 Observed text composition aspects in Eda's texts

		Placement of Text Elements			**Foregrounding / Backgrounding**		**Degree of Framing/ Relation**			**Heading/ Subheading**		**Relative Size**
Phase	Text	L/R	R/L	Centering	Critical	Peripheral	Line Zones	Colored Zones	Arrow	Font Size	Font Color	YES NO
Aw	1	X								X	X	X
	2	X					X			X	X	X
1	1			X	X	X		X	X	X		X
	2	X								X		

Table 4.25 Observed text composition aspects in Eda's texts (cont'd)

	3	X							X	X		
	1	X					X	X	X	X	X	
2	2			X	X	X	X	X	X	X		X
	3			X	X	X	X	X	X	X	X	X
	4			X	X	X		X	X	X		X

Table 4.25 demonstrates the observed text composition features (syntagmatic dimension features) of all the texts designed by Eda in all phases of the implementation. When the texts of the awareness phase are analyzed, it is seen that all two texts are centered oriented in terms of placement of texts elements and critical aspects are not foregrounded. The compositional aspects in the texts, font sizing, font coloring, and the relative sizing of the text elements.

In the HLT1, two of three texts are left/right oriented and the first text involves foregrounding/backgrounding of aspects. The second text in HLT1 is evaluated quite poor in terms of compositional aspects. This text has only font sizing of the heading as a compositional feature. Third text in HLT1 has additionally colored zones. Texts designed in HLT2 have relatively better compositional features. The first text (first iteration) does not involve centering orientation and foregrounding and backgrounding aspects. As same with the case of Sude, Eda understood better the strategies of effective multimodal text composition after the further development applied to the intervention (live instruction) and the effect of this development was well observed in second and third iteration of HLT2. The developmental trend in compositional aspects (textual meaning) can be seen in the aimed progress of the intervention.

4.4 Final Product (PD-MUST)

The draft intervention model with its parts was prototyped and developed through empirical findings gathered from the desing experiments. The draft model includes the design principles and intervention model. These two products were revised and developed. The developed products are presented as below.

4.4.1 Design Principles

4.4.1.1 Theoretical Design Principles

1. Learning is a mediated action. Learning is a design, and it includes internal and external design of representations embedded in the immediate learning environment.
2. "Learning", consequently, is defined as an increased capacity to use signs and engage meaningfully in different situations. Learning is here understood as a process of interpretation and sign production. The use of modes and media in processes of interpretation and construction is here central for the understanding of learning activities. Learning is a dynamic re-representation process in which students re-represent the information and presentations that teachers present in semiotic resources in the classroom.
3. Multimodal learning environment requires representational competent teacher. The teacher is expected to harmonize and orchestrate semiotic sources and modes effectively to design a meaningful teaching experience to engage, motivate, and educate students.
4. Discourse of science and science texts are inherently multimodal and each mode deploted in a text has their own characteristic meaning making potential.
5. The semiotic construction of scientific knowledge involves use of diverse modes and semiotic resources and teaching and learning in the science classroom is a multisemiotic experience.
6. Concepts, processes, entities, and circumstances are demonstrated through semiotic resources and the choices in use and compositional arrangement of

these resources affect demonstrated meaning and affect meaning making of the content.

7. Semiotic resources in a science text have topological and typological kind of meanings and the combination of these meaning types helps to contextualization of meaning.
8. Since, semiotic resources, modes, and design characteristics of a text affect the internalized meaning and externalized meaning, they have a potential to impact on the creative learning resources.
9. Students are active designers of their learning processes. They view, manipulate, interpret, transform teacher's available multimodal representations into new and meaningful ones.
10. The knowledge units in a science text do not have equal importance and there is hierarchy of criticalness of different knowledge units of a text.
11. The semiotic resource and mode choices and composition of them should be done according to the critical hierarchy and the discernibility of knowledge units can be arranged accordingly.
12. Having multimodal didactic text design competency may be gained through specifically developed interventions which enables teachers transform their knowledge to creative products.

4.4.1.2 Practical Draft Design Principles

1. While the teachers prepare learning resources, they should provide well designed sign system of information instead of well-designed information.
2. Teachers should present their pedagogical content knowledge and conceptual knowledge to students by designing them in multimodal texts or by harmonizing and organizing available designs
3. A MDST has paradigmatic and syntagmatic dimensions which affect meaning making of the content and semiotic construction of scientific knowledge in both internalized and externalized learning products.
4. Recognizing the forms and functions of different semiotic resources and modes and make conscious system choices when required.

5. Deployment of semiotic resources that have different meaning types (topological and typological) to demonstrate a meaning unit helps to contextualize meaning. This increases the richness of learning resources and concretization of the content.
6. An understanding of the meaning making potentials of different modes helps to effective use of semiotic resources in designing a text, so, increasing the meaning making potential of the text.
7. The design of a didactic text is initiated by the learning goals and intentions.
8. The choices of semiotic resources and modes are done according to the affordance or meaning making potentials of these resources.
9. Determining the important and critical aspects of a content parallel to learning intentions and embrace a social semiotic reasoning while designing a text to teach the content.
10. The compositional aspects including dimensions of text elements, locations, and the relation between these elements should be arranges regarding the hierarchy of criticalness among the different units of the texts.
11. Not only dividing the text into different meaning units helps to demonstrate the relation between different pieces of knowledge, but it also increases the semiotic economy in the text.
12. An intervention that aims to train science teachers to promote MDST design competency may involve awareness, recognize, overt instruction, and feedback learning activities.
13. Overt instruction for providing explicit knowledge about multimodal didactic text design should involve instruction video, direct instruction (scaffolding), and a handbook guide that provides information during design.

The draft intervention model includes two HLTs. These learning trajectories were initially hypothetical and after the prototyping process were evolved to learning trajectories, which can be used as a final product. As said earlier, each learning trajectory is a pedagogical process, which involve its learning goals, content, learning activities and assessment tool. The assessment tools are the interview questions and the STOP, which are given in Appendices A, D, and E.

4.4.2 Learning Trajectories

4.4.2.1 Learning Trajectory 1

The LT1 focuses on the paradigmatic choices in multimodal didactic science text design. The learning goals and learning activities including implementation sequence are given in below.

Learning goals. Teachers will be able to;

1. Identify, classify, and differentiate participants (concepts and entities), processes, and circumstances of a science content.
2. Identify, classify, and differentiate meaning relationship types between the participants taking part in the content.
3. Recognize, classiff, and differentiate typological and topological meaning types of disciplinary relevant aspects.
4. Implement, select, seconstruct, and coordinate semiotic resources and resource types that offer ease of understanding (disciplinary and pedagogic affordance).
5. Identify, classify, use, select mode concept and mode types.
6. Categorize, contrast, and distinguish the affordance of meaning making power (affordance) of mode types.
7. Use, differentiate, organize, suitable mode to represent the type of meaning and meaning relationship.
8. Understand and explain concept of multimodality
9. Identify, understand, use, organize, and generate multimodal texts

In order for addressing these learning goals following learning activities (see Figure 4.74) are developed. These activities are awareness, recognize, overt instruction (video instruction and handbook), text design, and feedback. In the awareness activity, the ISToGs are asked about their views, knowledge, and information about classroom practices regarding didactic texts, effect of these texts on meaning making of scientific knowledge and learning products, multimodal nature of these texts. In the recognize part, ISTs are provided with a learning environment where they experience various MDSTs. Next, they discuss the semiotic resource and mode choices and effects of these resources on the meaning making of the content and how they can affect the learning products designed by students. The overt instruction phase involves two elements. The first of them is video instruction where explicit information about meaning making, disciplinary relevant aspects, transitivity system elements, meaning types, meaning relation types, semiotic resources, mode concept, multimodal texts, the strategies for selecting appropriate semiotic resources and modes in semiotic construction of scientific knowledge. The handbook plays a guide role in designing texts. Next activity is design activity, where ISTs design multimodal text according to their previous learning experiences. Here, a specific content in monomodal (language) mode is given and translated into multimodal texts. Final learning activity is the feedback activity where ISTs are given with feedbacks to their designs. Within this activity, ISToGs get an opportunity to see effective and ineffective design features. Furthermore, if needed, further multimodal texts can be designed, and feedbacks can be given.

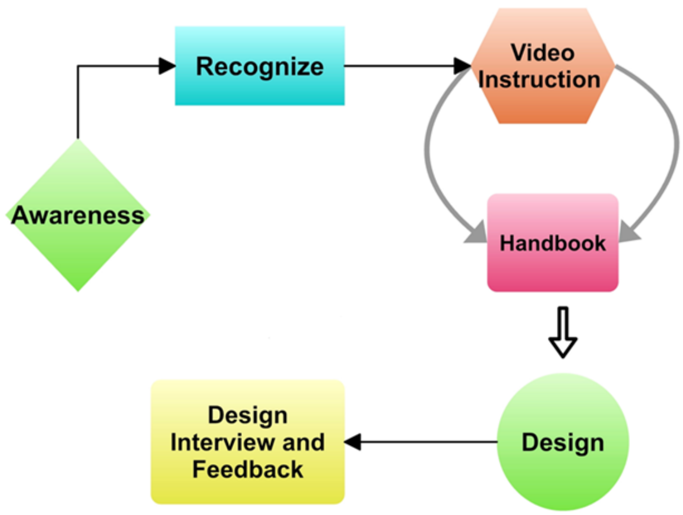

Figure 4.74 Learning activity sequences of LT1

4.4.2.2. Learning Trajectory 2

The LT2 focuses on the syntagmatic choices in multimodal didactic science text design. The learning goals and learning activities including implementation sequence are given in below.

Learning goals. Teachers will be able to;

1. Identify, contrast, and differentiate disciplinary relevant aspects of the object of learning or content.
2. Recognize, compare, differentiate Important, critical, characteristics or aspects within the disciplinary relevant aspects.
3. Classify, organize, and plan the hierarchical order of the information that the content has as theme (focal), peripheral, and margin according to the criticalness level.
4. Implement, organize, and produce dimensional, spatial, and relational text composition arrangement between representations that represent the features or aspects according to the criticality-importance hierarchy.
5. Create explicit variation around critical aspects to make critical aspects more understandable.

To address the learning goals, following learning activities are developed (see Figure 4.75). Awareness, recognize, overt instruction (video instruction, handbook, and live instruction), text design, and design feedbacks. In the awareness activity, the ISTs are asked about their views, knowledge, and information about classroom practices regarding compositional text aspects and effects of these compositional aspects on meaning making of scientific knowledge. In the recognize part, ISTs are provided with a learning environment where they experience various multimodal text structures. The overt instruction step includes three learning activities. In the first activity, explicit information about the syntagmatic choices for text composition, text composition strategies which are informed by variation theory of learning. The live instruction involves live or face-to-face scaffolding for text design. The handbook plays a guide role in determining effective text composition features during design. The design activity involves designing multimodal didactic science texts on a given topic. In the designs, the strategies given in LT1 and in this learning trajectory are expected. Last learning activity is the feedback activity where ISTs are given with feedbacks to compositional design strategies in their designs. Within this activity, ISTs see effective and ineffective compositional strategies.

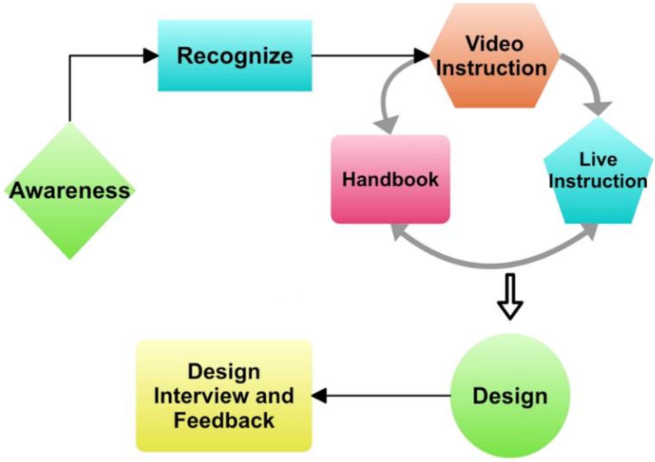

Figure 4.75 Learning activity sequences of LT2

5
RESULTS AND DISCUSSION

Gifted students are considered as superior in inventiveness, imagination, and problem-solving skills domains (Gagne, 1985; Renzulli, 2005). Teaching science of gifted students requires certain pedagogical strategies (Chowdhury, 2016). The pedagogical competencies and strategies of science teachers influence the meaning making of science content and the creativity of internalized and externalized learning products (Bailey et al., 2016; Besançon, 2013; VanTassel-Baska et al., 1998). Numerous studies (Danielsson & Selander, 2016; Jewitt et al., 2001; Yeo & Nielsen, 2020) have demonstrated the importance of multimodal didactic representations and texts on the meaning making and learning of scientific knowledge. Additionally, according to Vygotsky's theory on the dialectic relationship between internal and external processes of creativity, creativity requires to "build individual understandings and insights regarding the surrounding culture, and creativity allowed innovation and change in the culture itself". The most striking view of system models (Csikszentmihalyi, 1990) on the creativity is that it is not attributed to only "characteristics of particular people or products", but "as an interaction among the person, product, and environment. In this respects, the representations used in science classrooms affect the internalized learning products (meaning-making) and the externalized learning products. Bailey et al. (2016) notes that the contemporary approaches in gifted science education focuses on helping students produce the scientific knowledge as the products of scientific inquiry conducted in science classroom.

Classroom as a learning environment, which involves mediating tools or resources for internalization and externalization of scientific knowledge (Eilam et al., 2014). While the internalization can be seen as the cognitive processes of meaning making, the externalization can be viewed as the material products, which are student-generated or designed learning products. The materials lying in the learning environment are key elements in shaping the meaning making of scientific knowledge and the creativity in materialized learning products. Didactic science texts or representations, as mediating materials or tools, are crucial elements of the learning environment. Furthermore, these texts communicate scientific knowledge as a part of discourse of science (Jaipal, 2010). In this respect, as the didactic science texts plays an important role in meaning making of scientific knowledge and shaping the creativity in the materialized learning products by providing affordances (Glăveanu, 2013). The discourse of science and scientific texts are conceptualized as multimodal which posit that the meaning take place with the collaboration and complementation of various modes. The meaning making processes in science classroom are explained by social semiotic theory that conceives the mediating tools as semiotic resources.

In this respect, this study focused on the MDST design competencies of ISTOGs of middle school level gifted students. Since recognizing the meaning making value of multimodal texts, using in different contexts, and designing multimodal texts requires representational competency (DiSessa, 2004; Stieff, 2011), development of multimodal text design competency requires a well-designed and learner-oriented learning experiences (Andersen & Munksby, 2018; Eilam et al., 2014). However, the literature review of this study demonstrated that there is no such a professional development program for science teachers of gifted students. In this respect, this study aimed to develop an intervention model (PD-MUST), which fosters ISToGs to promote MDST design competencies. In this aim, we theoretically developed an intervention model (professional development training program) and practically developed the program's design principles and learning trajectories with learning goals, activities and assessment tools.

In this respect, the PD-MUST is for professional development program for ISToGs. What the developed program consists of or what was developed? Learning goals, content, learning activities, and text evaluation tools were developed. These products were developed for all three HLTs. What is more, the development of the training model is informed by the design principles, which are other products of the study. For these ingredients of a pedagogic activity were developed in a design-based pedagogical approach which supports transformation of knowledge and design. Therefore, educational design research based methodology was employed to develop such a teacher professional development program. The orientation of this design research is on researching on intervention where the aim is on the "knowledge about particular type of intervention" (McKenney & Reeves, 2012, p. 136). In this regard, the intervention model including design principles and hypothetical learning trajectories was theoretically developed and prototyped in actual learning settings. The development of the model is monitored in the development of specific comprehensions, skills, and competencies on MDSTs of the participants. In this regard, the discussion part involves; (1) discussion on participants' development and (2) the discussion on the development process of the intervention model.

5.1 Discussion on Individual Participants' Development of Multimodal Text Design

This part includes the discussions of (1) participants' initial awareness and competency levels regarding designing multimodal didactic science texts and (2) the developmental progress throughout the intervention process (prototyping) of the study.

5.1.1 Discussion on Awareness Phase

The initial or pre-intervention part of the research aimed to do gather views, actual practices, and text design competency levels of the participants about designing MDSTs. This phase also constituted the awareness phase, which is considered as the first step of the intervention model. The domain knowledge of teachers impacts their teaching practices (Loughran et al., 2004) and their representational practices as well (Waldrip et al., 2010). In this study, teachers' views, knowledge and representational practices are examined from two data sources that are interviews and participants texts. Here, similar strategy with Eilam et al. (2014) was followed and found successful. The interview data demonstrates that, although the literature, (i.e. Yeo & Nielsen, 2020), insists that the texts used in teaching and learning have substantial role in student learning and conception, participants do not generally consider selecting or designing texts as a well-planned pedagogical strategy before teaching of scientific knowledge. This finding was similar to the findings of Patron et al. (2017).

The second salient data figured out in the awareness interviews are that, when asked, participant teachers do not include the texts as factors to influence meaning making of science concepts. Participants point out the importance of student active learning activities such as designing a model, doing an experiment, or group working. However, these kind of learning activities mostly focus on the externalization and experiments. Human cognitive development is mostly shaped by the learning of meaning of symbols, use of tools, and communication of specialized knowledge with the meaningful tools (Bruner, 1964). This kind of development take place dominantly through internalization processes, which are mainly shaped by the semiotic resources of meaning, embedded in the learning environment. It can be discussed that, since the representations used in learning activities both affect the learning and the learning products, designs of these texts should be incorporated into the pedagogic strategies and repertoire. The reasons of why participant teachers do not consider text design as a part of teaching strategies before and why teachers have limited didactic text design strategies may be that they do not view design of these texts as factors to influence learning and learning products.

Furthermore, while participants express that they employ various modes in their representations, they had limited awareness about the multimodal nature scientific knowledge and how each mode contribute to total meaning posed by the texts. This finding was quite similar to the views of Eilam et al. (2014) and Yeo and Nielsen (2020). This was evident from the findings that participants see the language mode as the main actor for the construction of scientific knowledge and have limited knowledge of affordances provided by other modes in meaning making of concepts.

The limited awareness about the role of didactic texts or representations and their designs can be observed in the didactic texts, which are designed by the participants for their actual teaching practices. The SF-MDA of the texts in the perspective of VTL is presented in the finding parts. As stated early, the didactic science texts are analyzed within two dimensions. The first dimension involves the paradigmatic choices, which demonstrates the semiotic resources, and modes are chosen to demonstrate the scientific knowledge. In this dimension, teachers are expected to employ the semiotic resources and modes which have best disciplinary affordance to demonstrate meaning and which have the best contextualizing power for extending meaning for better understanding. This first dimension deals with the demonstration of the ideational meaning, and how different modes are complement each other regarding the ISMs and mixed-mode semiosis. Second dimension of text design constitutes syntagmatic choices (compositional features of text) which refers to the arrangement of chosen semiotic resources and modes in the text. These syntagmatic choices are informed by the VTL to demonstrate textual meaning. The analysis of didactic science texts yielded that mode level is dominantly one-mode, which means that the scientific knowledge is represented with limited resources of meaning and the contextualization of meaning is low. This can be understood from the types of meaning demonstrated by the paradigmatic choices. The ISMs constructed between different modes are seen as the way of combination and collaboration to demonstrate meaning. The variations in these combinations can be viewed as effective use of modes and their affordance to demonstrate meaning. The analysis demonstrated that the frequency of various ISMs is low which refers that the used modes have limited affordance in demonstrating scientific knowledge and low meaning making power. Furthermore, as stated early creating explicit variations around the critical aspects of the content of the text helps students discern these critical aspects easily and understand better. The results demonstrates that the use of explicit variation in representations is around seven percent. This data cannot be evaluated as sufficient or insufficient but provides an initial information before the interventions.

Regarding the compositional aspects of the texts, most of the texts were designed in a way that the chosen semiotic resources are composed with limited pedagogical strategies. This situation causes a situation where students cannot perceive or discern the critical aspects of the content and cause poor understanding. This shows us that both the choices in paradigmatic and syntagmatic dimensions of didactic texts are informed by pedagogic intentions, which generally depend on the learning goals. The interview data yielded that, most of the participants' strategy and intention in compositional aspects is attracting attention which is informed by aesthetic concerns and limited pedagogical concerns. The most salient compositional feature observed is the use of heading sizing and coloring. Furthermore, it was observed that some participants successfully incorporated colored zoned to separate meaning units in the text. Furthermore, use of arrows to relate different elements and meaning units of the text is common. These findings were considered big motivations to help these teachers to strengthen their pedagogical strategies in didactic text design.

The analysis of data shows that the paradigmatic dimensions and syntagmatic dimensions shows low MDST design competencies. This situation can be still attributed to the low awareness of roles of didactic texts or representations in communication and meaning making of scientific knowledge. In front of these findings, since such competencies require representational competency (DiSessa, 2004), teachers needed to be immersed in learning experiences which are specifically designed. Furthermore, literacy practices in the digital screen age are conceptualized as multimodal and both teachers and students are intensively immersed in these texts in both in and out of school. In this regard, the initial findings also imply that the design and use of these texts are habitual where the conscious design with a pedagogic strategy is rarely observed. This study assumed that the absence of conscious design is normal since such design competency requires specific intervention or learning experiences. In brief, the initial data demonstrated that the level of awareness about the roles, functions, and nature of didactic science texts is limited. This finding is similar to the findings of Patron et al. (2017) who studied on the social semiotic reasoning and representational practices of chemistry teachers. These studies demonstrated that the reasoning of participant teachers are limited similar to this study. Also, this finding is parallel to Eilam & Gilbert (2014), who posit that science teachers have limited awareness about the affordances and challenges posed by representations used in science teaching. Therefore, since the awareness part of the study was also the state, where the problem is determined, the development of a PD-MUST foster the representational competency levels of ISToGs is a solution proposal.

5.1.2 Discussion on Implementation Phase

As stated earlier, the developed training program focuses on two dimensions of texts design and the intervention has three phases, which are awareness phase, HLT1, and HLT2. While HLT1 focused on the paradigmatic dimension of multimodal didactic science texts, the HLT2 focused on the syntagmatic dimension of these texts. HLT1 and HLT2 have awareness, recognize, overt instruction, evaluation-feedback and re-design learning activities. The awareness phase data is discussed above. The recognize learning activities provided situated practice for learners who experienced various instances and examples of texts design. Therefore, in the recognize activities involves researcher's design of multimodal texts and participants' responses to the open-ended discussion questions.

The recognize activity of HLT1 was effective on situating participants' perceptions about the mode level and affordances of different modes on meaning making of the content. One salient effect of mode levels and use of various semiotic resources in the text is that participants realized more concepts and entities taking part in the content. Furthermore, the paradigmatic choices affected the recognition of meaning relationships between the concepts and entities. For example, one participant responded that "*it is easier to see the spatial relationships between the concepts and entities*" and another responded that "*mathematical formula helps to see the quantitative relationship between the concepts in a short time"*. These two findings are parallel to findings of Tang et al. (2011) who attributed such responses to the affordance of the used modes. Another crucial point is that participants implicitly valued the existence of semiotic resources and modes that present topological meaning. The existence of typological and topological meaning leads to mainly three effects in a MDST. These effects are (1) the concretization of the content, (2) effect on scaffolding, and (3) semiotic economy. Teachers' views on the scaffolding effect was surprising but parallel to the study of Meneses et al. (2018). Teachers mainly posit that the use of visual imagery mode elements and language elements helps students conceive the scientific knowledge or content in way that is quite similar to the teachers' conceptions. Meneses et al.'s (2018) study pointed out the scaffolding effect of multimodal text design on the reading comprehension of students and recommended that the design of the text can be a scaffolding factor for student understanding.

The recognize part of HLT1 helped participants to experience different mode levels and semiotic resources. Parallel to the study of The New London Group (1996), the effect of situated practice is observed. This experience is shaped by asking them to think these variations in a way that they can influence student understanding of the presented content. The recognize activity was effective as suggested by Cope and Kalantzis (2015) 'learning by design' approach. Therefore, at the end of this learning activity participants recognized the effect of the paradigmatic choices in demonstrating ideational meaning on the meaning making of the content.

In after the overt instruction, evaluation, and feedback activities, the analysis of all texts demonstrated a sharp change in the aspects of paradigmatic dimension of texts. The mode-level in components of texts designed in HLT1 has been changed in a comparison to awareness phase. The mode level in texts sharply increased. This means that, to demonstrate or present scientific knowledge more modes are employed and complemented. This also means that, the mode level in components of texts increased. Nonetheless, the mode level in texts cannot guarantee texts of sole criteria for being meaningful in communicating scientific knowledge. One main function of multimodal ensembles is expected to demonstrate the meaning as extended and contextualized. As said earlier, the existence of mixed-mode semiosis where typological and topological meaning appear in showing information within a component. Parallel to the increase in mode level in texts, the percentage of components which demonstrates typological and topological meaning dramatically increased. With the increase of mode level, this increase can be seen as an ensuring factor for the increase in meaning making power of designed texts. Furthermore, when the variety and frequency of construction of ISMs, an increase is observed for both criteria. For example, semiotic adaption was not observed in the texts designed in the awareness phase. This ISM is generally observed within the texts that involve quantitative meaning relationships between the concepts or entities (participants). Likewise, for example, values of a participant is given in a table or chart and this situation was attributed to semiotic adaption by O'Halloran (2007). Therefore, this

ISM is generally observed when the language and mathematical mode complement each other. Although there were texts that involve quantitative meaning relationships among participants, this ISM was not constructed in the texts of awareness phase. The increase in the use of this ISM is another sign of conscious choice in the modes and semiotic resources. This inference was corroborated in the design interviews. In the end of HLT1, for example, one participant stated that "*since I thought that this mode or modes are best to demonstrate the meaning I intended, I choose this mode*". The reasons behind their choices were parallel to the instruction given in overt instruction and feedback phases.

However, this increase cannot be thought as only the effect of overt instruction given in two iterations. It can be interpreted as that, the questions asked in awareness phase, and the texts given in recognize phase had substantial effect. The most crucial effect of overt instruction and feedbacks were seen in the conscious choices in modes and semiotic resources. The effect of direct instruction was similar to findings and remarks of Cope and Kalantzis (2015), Nam and Cho (2016), and Tippett (2011). In the first iteration, after the overt instruction video, most of the participants were unclear in terms of the concept of affordance. The handbook and feedbacks helped participants understand the concept of affordance better and pair information with appropriate modes easily.

Lastly, the analysis of more than two hundred components in awareness phase and more than one hundred and eighty components in HLT1 demonstrated that there was no change in the percentage of variation types in texts. The main reason of this unchanging situation is that the intervention or instruction was not given in HLT1. Since giving implicit or explicit variation is considered a part of ideational meaning in a text, the use of variation is given in HLT1 part which involves paradigmatic choices for representing ideational meaning. As the intervention regarding creating variation around critical aspects is given in HLT2, change in uses is expected in that phase.

Mode levels in demonstrating transitivity system elements of disciplinary relevant aspects demonstrate that the most changing mode level is in representing participants and the least change was observed in processes. Demonstration of participants can be considered as easier since language, visual imagery, or mathematical symbolisms can represent a participant together. However, this situation is not same with representation of processes, which were generally represented mostly with language mode. As Akaygun and Jones (2010) remark, represented dynamical processes are demonstrated with verbs since the language has the best affordance in representing processes. This finding is consistent with the findings of Akaygun and Jones (2010) and Oliveira et al. (2014). Processes are dominantly shown through language mode. Visual imagery mode (specifically arrows) is also used to demonstrate processes. For example, Ebru's in the HLT1 shown above is a good example. In this text, arrows are used to demonstrate processes such as "emit", "penetration", or "absorption". It was observed that semiotic mixing intersemiotic mechanism is generally constructed when processes are represented with visual imagery modes. Furthermore, when the processes are represented with mathematical mode, the semiotic transition intersemiotic mechanism is generally observed. This shows the easy translation between language and mathematic mode since it has specialized symbol systems including participants (such as X), processes (such as =), and circumstances (such as (>).

In the HLT1, there was observed a sharp increase in the paradigmatic dimension aspects of the texts. The individual analysis of the developmental trends and qualitative analysis of the texts yields parallel changes. This parallelism was not firstly observed after the overt instruction, but it was dominantly observed after the second iteration of HLT1 where handbook and feedbacks are given. When the syntagmatic dimension aspects of texts are analyzed, it was observed that the textual features of texts are slightly different from the texts designed in awareness phase. For example, most of the text are still left-right or right-left oriented and only one fourth of texts foregrounded critical aspects of the texts. At this point, foregrounding of critical aspects is done in the aim of using some semiotic resources commonly. The second text of Ebru in HLT1 is a good example of this situation here. A common big image of a plant with leaves is put in the center of the text to use the semiotic resources common and easily relate the elements. The most salient compositional features of texts are, like awareness phase, colored fonts, font sizing, and use of arrow. This finding can be interpreted as that since the HLT1 did not affect on the text design competency regarding compositional aspects, significant change was not observed. In brief, for HLT1, the effect of intervention is observed in the participants text design competencies regarding making paradigmatic choices in the semiotic construction of scientific knowledge.

When the data gathered in HLT 2 slight changes are observed in the paradigmatic system choices to demonstrate ideational meaning in text designs. Regarding the ideational meaning significant changes was observed in the types of variation for critical aspects. This change can be attributed to the effects of learning activities and the instruction given in HLT2. In the awareness phase, participants showed limited understanding and comprehension on how compositional structure of a text can influence the meaning made from that text. In the recognize phase, as stated earlier, two texts with same content and same paradigmatic choices but with different compositional structures are presented. The texts were successful in helping participants to recognize that the compositional features can help learners discern the critical aspects or facets of the content easier, so foster understanding. Understanding the fact that, the spatial, dimensional, and relational arrangements in a multimodal text affect meaning making of the content was crucial. For example, split attention (Herrlinger et al., 2017) can negatively effect understanding of the information since the meaning making resources in the texts are positioned with poor positioning.

Furthermore, text structure can organize meaning into a coherent structure where different meaning units are related. In the discussion interview, some participants stated that *"it is easier to follow what is going in the text".* Following three iterations including overt instruction and feedbacks, the compositional aspects of texts significantly change with regard to awareness and the HLT1. Most of the texts are centered oriented and foregrounded the critical aspects for better discernment of learners. One significant point here is that, the use of relative sizing was also commonly used in previous texts. However, foregrounding and backgrounding were not observed in similar frequency. Normally, relative sizing is expected for foregrounding or backgrounding. Nevertheless, the initial interview data revealed that participants were randomly using the relative sizing aspects for the aim of getting attraction. This aim can be thought as similar to making critical aspects more discernible. However, participants were using this strategy without determining the critical aspects in aligned with learning goals. This finding shows that the text composition strategies of teachers are informed by a pedagogical strategy.

One crucial thing here is that participants, participants understood the importance of determining the disciplinary relevant aspects, then determining the thematic patterns within these aspects, and determining the criticalness hierarchy in designing compositional aspects. Some participants' propositions were informative about how determining these aspects help to design a coherent text structure. Firstly, figuring out the DRAs helps dividing the text into smaller meaning units. Second, the thematic patterning help to determine meaning relationships between these smaller units, so make it easier to relate them. Finally, the determining the criticalness hierarchy helps decide which meaning units are to be foregrounded and which are to be backgrounded. During the interviews, participants stated the critical aspects as the most important message a text giving. At the end of the HLT2, as expected, it was observed from the qualitative and quantitative data that participant's competencies in designing compositional aspects of a MDST are significantly enhanced after three iterations.

Another remarkable, finding is that all five texts are centered oriented. Obtaining this result was one aim of the intervention given in the HLT2. However, the DRAs, meaning relationships among participants, or process types in the content can help the designer construct a center-oriented composition. Since the carbon cycle topic includes cyclic processes use of arrows and relating components through the cyclic processes is easier than, for example, designing a center-oriented text structure, which demonstrate the topic of Ohm's law. In parallel, in the design interview, participants point out that creating a centered- oriented was relatively easier. This finding demonstrates that the content with the meaning relationships across transitivity system elements is a factor for in designing texts. To sum up, (1) the awareness of participant science teachers regarding the role didactic texts in meaning making of scientific content knowledge and learning products and (2) their text design competencies were found limited. Through out the specific intervention processes, enhancements in the competencies on designing paradigmatic and syntagmatic dimension aspects of MDST were observed.

5.2 Discussion on Development of Training Program

This study has developed a specific intervention model (PD-MUST) by deploying the EDR methodology. The intervention model is a solution proposal for a determined problem. The determined problem contains two issues. First, the awareness of ISToGs are limited regarding the effect of didactic science texts on meaning making and designing creative learning products. Second, the MDST design competency levels were found low. To solve this problem, this study have developed on solution proposal to cope with this problem. This solution proposal is the PD-MUST model that involve design principles and hypothetical learning trajectories for enhancing MDST design competency of ISToGs.

The solution proposal was firstly developed as draft. Development of draft intervention model was informed by theory, previous literature, meeting with experts, observing classroom practices, and gathering data from real practitioners. It can be said that all these sources provided distinct data which illuminate distinct aspects of the issue. Therefore, it can be said that in developing draft intervention model, gathering data from diverse stakeholders and data resources is quite crucial for both precise determination of the problem and developing proposals. The value of obtaining initial data from different stakeholders in the field is highlighted by McKenney and Reeves (2012). Observing classroom practices, interviewing, and analyzing texts gave ample data and helped to triangulate data for generating sound decision regarding solution proposal. Therefore, as McKenney and Reeves (2012) argue, precise definition of the problem and gathering data from diverse sources help developing more feasible and applicable implementation model.

The prototyping or development of the PD-MUST involved prototyping of design principles and the hypothetical learning trajectories. The development of the design principles was done mostly for practical design principles, which is given above. Fortunately, design principles involving awareness phases and recognize phases were worked as in expected. However, the design principles regarding overt instruction were not sufficient. Therefore, for practical design principles more elements added. The practical design principles illuminate mainly multimodal text design activities within the design-based pedagogy that purports to realize the transformation of learning into creative products/designs. It was seen that video instruction for explicit teaching meaning making processes (semiosis) and designing MDSTs is not sufficient. For an effective framing and scaffolding, the learning live instruction and a guiding learning resource are essential. Therefore, the practical design principles were modified according to these empirical finding.

Andersen and Munksby (2018) developed design principles for developing science students' representational competency in their design study. The study highlights that being representationally competent leads better understanding of science. In this respect, three design principles designed in iterative cyclic design experiments. However, the study involved mostly learning by doing experiences where specific text design instructions (critical framing) and an organized assessment strategy for representational competency was not applied. In this study, two HLTs that have their own learning goals, content, learning activities, assessment strategies, and pedagogical approach. The HLTs were informed by theoretical and practical design principles. Furthermore, Yeo and Nielsen (2020) point out the approaches for the functions of multiple modes of representation. Accordingly, interpretive approach where students interpret the existing multimodal texts, and constructive where students construct and produce multimodal representations. The PD-MUST is not at any end of this continuum; it is at the middle but near to interpretive. However, this study sees these approaches as separate phenomena but related and sequential. In other words, it is assumed that the interpretation of existing representations affects the constructed or designed one. This idea is originated to the internalization and externalization processes. Kim (2015) conducted a multimodal modelling study in which pre-service science teachers designed multimodal models to deep their content knowledge and multimodal modelling competencies. The learning activities were oriented by 'learning by doing' activities. Since, this study involves learning from activities (such as overt instruction), one difference of this design based research from the research of Kim (2015) that, this study is much more interventionist that involves more critical framing or direct instruction.

Ainsworth (2006) claims that the multiple external representations provide unique benefits for meaning making and learning. Accordingly, it was expressed that, taking following aspects of learning into account can help to see the effectiveness of these representations. The first consideration is design parameters that are "unique to learning with or by multiple external representations, second, the functions which are served by multiple external representations for fostering learning, and finally, "the cognitive tasks that must be undertaken by a learner in interacting with multiple external representation. In this respect, in the PD-MUST, these parameters are considered for designing effective MDSTs. For the first parameter, the design parameters in this study were mainly determined by the design principles. The design parameters were mainly choose appropriate semiotic resources and modes to demonstrate DRAs, and composing these resources of meaning making into a coherent text structure which is informed by pedagogic strategies of teachers. In this respect, it was observed that the determination of design parameters is quite crucial in giving a sound and understandable ways for teaching a meta-representational text design competency. Regarding second parameter of Ainsworth (2006), the representations designed by participants are expected to communicate the scientific knowledge in a meaningful way, which aims to demonstrate the all DRAs with the criticalness hierarchy and creating explicit variation around the critical aspects. Regarding the cognitive tasks in interacting with MDSTs, the texts are designed in a way to extend and contextualize meaning, therefore, providing information in epistemologically high valued disciplinary scientific representations (representations that have typological meaning) and with representations which opens up the interpretative space (representations that have topological meaning).

The text design strategies provided by DeFT framework of (Ainsworth, 2006) are similar to the strategies suggested in this study. However, one crucial difference is that, DeFT model's audience is learners and the model is developed for better understanding of the scientific knowledge by learning with multiple representations. Here, the appropriate strategies for designing multimodal texts, which students will be provided in the lessons, are proposed. Nonetheless, the principles in designing external representations informed the design principles of the intervention model. The strategy presented by Ainsworth (2006) posits that student science learning can be fostered if the student can do the following operations. The student (1) understands the form of a representation, (2) understands the relationship between a representation and the domain, (3) understands how to select an appropriate representation, (4) understands how to construct an appropriate representation, and (5) understands how to relate representations. This study's strategy was further included with awareness, feedback and evaluation activities. These three activities first checking the existing knowledge and competency in designing texts, taking suggestions from other resources, evaluating the values of other texts in terms of their pedagogical values for meaning making of the texts.

Learning approaches oft he HLTs are informed by design-based pedagogy which aims to transform the information to creative learning trajectories. The learning activities within an HLT involves awareness, recognize, overt instruction, feedbacks, re-design, and peer evaluation. In the beginning, participants had very limited knowledge and conscious practices for MDST design. From this initial point, the participants advanced to evaluate multimodal designs created by another participant. Participants developed their design strategies especially after the overt instruction activities where explicit knowledge was provided with exemplary applications. This helped participants obtain design strategies in short time which is also stated as possible by DiSessa (2004). DiSessa (2004) posits that with appropriate intervention representational competency skills can be improved in a relatively short time. The transformation of learning, in accordance to the Bloom's revised taxonomy by Anderson and Krathwoll (2001) was observed. This helped to participants not only designing a multimodal text on a given content, but also evaluating the other texts with regard to certain criteria. As well known, teacher do not always design their own representations, they also choose from texts, which are prepared or designed by others. Therefore, by knowing how to evaluate texts will help them to choose effective texts for their actual teaching practices.

The development of each individual HLT was on done within the iterative and cyclic processes. Each cycle has preparation, implementation, evaluation, development, and another cycle, if necessary. The repetition of such a cyclic design experiment is seen as iteration. It was observed that effective development requires, well determined learning goals which must be measurable with a certain assessment tool. These two factors help to see where the problem is and what to be developed. However, design interviews and evaluation interviews are also crucial factors in determining the problem or insufficient aspects of competency. The interviews mainly served two critical facilities. First, they helped to better or appropriate understand the design intentions. Second, they maintained keeping in touch and motivating the participants during the implementation progress.

In development of HLT1, the efficiency of the intervention was observed through how well the participant make paradigmatic (semiotic resources and modes) choices in designing a multimodal text. The four texts developed in recognize phase and the discussion were the most effective activities for understanding the concept of affordance. This was a discussion activity for the affordances of diverse semiotic resources and modes. The discussion activity was seen an effective strategy in helping participants recognize the affordances. Parallel to Nam and Cho (2016) and Tang et al. (2016), this activity helped to experience rich environment of multimodal texts, compare them and evaluate the affordances provide by them. This finding is parallel to the findings of Andersen and Munksby (2018) and McDermott and Hand (2013). However, after the overt instruction phase, participants could not transform their understanding to designing desirable multimodal texts. The overt instruction included only video instruction developed/designed by the researcher. The video instruction was a direct instruction way that demonstrated strategies for appropriate choices of semiotic resources and modes. In the first iteration, the concept of affordance regarding meaning types was not understood at a satisfactory level. The mode levels and variety in ISM types were relatively limited. In solving the problem or developing this part of the intervention, the views of participants, and text analysis demonstrated that participants need a resource that they can easily apply as guide. This decision was also taken by reviewing previous studies. This situation is similar to Airey and Linder (2009) concept of disciplinary imitation.

Disciplinary imitation is similar to the concept of mimetic learning (Wulf, 2008). Here the participants followed the strategy proposed by the developed handbook in the second iteration of HLT1. The use of handbook was effective in providing direct instruction for text design as remarked by Tippett (2011). Therefore, as the satisfactory results were observed after the use of the handbook. The effect of use of handbook in the second iteration was observed especially on the construction of various ISMs and the mode levels in the components. It was observed that, with more text design and getting more feedbacks helped to participant advance from disciplinary imitators to disciplinary fluent designers. This disciplinary way of representation for teaching a content does not involve only the symbols in disciplinary ways of knowing, but also use affordances of different modes and semiotic resources that not bounded to a certain disciplinary knowledge.

In the development of HLT2, the design principles and draft HLT is also revised and strengthened for overt instruction. In this HLT, video instruction was found insufficient in the first iteration. In the first iteration, text placement, use of relative sizing, and the level of variation around critical aspects were not at satisfactory level since participants were not completely clear about the strategy provided by VTL. By the effect of the experience in the development of HLT1, handbook was given in the second iteration. However, it was seen that participants were still unclear in terms of understanding the pedagogical strategy behind arranging text composition. The pedagogical strategy provided by VTL informs to compositional arrangements of text. For example, one participant had a misconception about the criticalness hierarchy and relative foregrounding backgrounding the text elements. Since the handbook was still ineffective for an appropriate understanding text composition, live instruction in the third iteration was provided. This live instruction has a scaffolding role where participants are illuminated through their own representations and the feedbacks are given face to face in virtual environment. The role of live instruction or scaffolding in designing science texts was remarked in the study of Tang et al. (2011). However, in that study the researchers' role was more passive in which teacher participated discussions. Here, the teacher (researcher) has more authoritative role as the holder of knowledge (Roberts, 1996) in creating critical framing. This strategy helped to reveal the actual situation where participants fail and where they are strong. The reason of understanding difficulty regarding designing compositional aspects of the didactic multimodal texts seemed as in following; in HLT1, the resources were chosen from a reservoir system of disciplinary discourse. In the HLT2, participants were expected to pair two strategies coming from SFT and VTL. Therefore, adapting the strategical combinations to different contents was seen more complex. Therefore, further scaffolding was necessarily emerged. In the end, the overt instruction phase included video instruction, handbook, and live instruction. These development to the HLT has also influenced the design principles.

In each iteration, topics and the content of the texts were changed intentionally. There were two reasons behind this strategy. First, the target competency is a meta-strategy that involves content-independent design skills. This is called as meta-representation by DiSessa (2004). Secondly, different content helped to see understanding, practices, and claims of participants better since different content need different semiotic resources, modes, and has different critical aspects. Otherwise, giving feedbacks as text and designing it again with same content should be a motivation, not a practical knowledge. Therefore, although its implementation difficulties, use of different content in iteration helped monitor the development more realistically.

As said earlier, the implementation model is a combined pack of two HLTs and each of them focused on multimodal meaning making of scientific knowledge and different aspects of MDST design. In this regard, the PD-MUST, which is a training program for both pre-service and in-service science teachers of gifted learner, is the combination of two HLTs and design principles. The development of, as explained above, is based on theoretical knowledge and the knowledge based on actual practices. Therefore, the development process not only has given a product, but also theoretical and practical knowledge for further applications.

During the research, the evaluation interviews in the middle and in the end of the implementation provides valuable data in development of the intervention. Above, the support of participant's designs and design interviews were valuable, but they were not sufficient. As said by McKenney and Reeves (2012), a test toward the intervention was must to envisage participants' views on the intervention that they are exposed to. The middle evaluation model helped participants' challenges and opportunities in design activities regarding, design tools, given time for assignments, and the roles of the researcher. The findings of final evaluation interview imply that the effect of intervention helped them consciously choose from existing texts and design didactic texts in a more informed manner. It can be argued that the gained critical stance not only helps them using well-prepared multimodal texts, but also it can be reflected on the use or employment of other semiotic resources, such as videos or models. In the end, the intervention model with its learning goals, content, learning activities, assessment tools demonstrated a satisfactory and desirable effect on the MDST desing competencies of the participant ISToGs.

5.3 Implications and Limitations

For practical implications, this study demonstrates the implementation of a training model on MDST design and design principles. Furthermore, the development was done on online platforms, which can be considered in case of a similar interactive instructional design. The developing process provides insights and strategies for further researchers in the field of gifted education and multimodality. In this respect, the methodology of the study provides theoretical and practical knowledge about both working with a small group of participants for a long time and conducting research on virtual platforms. This should be considered in terms of several aspects. First, keeping the research on the track through synchronous and asynchronous digital learning environment/mediums and applications is one barrier to cope with. Frequent touch with participants, keeping their motivation high, and second, selecting the best tool for the research goals are also crucial factors. In this study, the selecting of tools were done according to mainly remote connection, design tools, data sharing, and participant interaction. What is more, the tools should be well-known by the participants. Third, since the time-sharing issues, researching with in-service teacher participants, who joined weekly design activities and other duties, the implementation of the research activities can be difficult. In these respects, any design researcher with similar settings, should consider daily life routines of participants and make implementation calendar as flexible as possible. Regarding ethical considerations, keeping the anonymity and confidentiality during the intervention process is key for ethical consideration. In this respect, during the design activities, participants were given with limited access to information of other participants or even texts in some activities.

The second aspect can be seen as the development progress of the product in educational design research family of methodologies. Within this study, it was seen that a design researchers should be open to any surprise since there is no one independent and dependent variable. The variables are dependent and changing. Therefore, the iterative and cyclic nature of educational design research must be understood, and, in each iteration, the treatment must be revised and developed according the literature, theoretical framework, and findings. Furthermore, these processes require a high patience from the researcher. The researcher always needs other people who are experts of one aspect of the study. This will also provide an alien eye, which can provide valuable ideas and contributions to the researcher who is highly immersed to the process. What is more, the design researcher studying on teachers' professional development should keep in mind the existing pedagogical and classroom habits, which can show a great resistance for change. Such factors can impede the progress of the research and increase the number of iterations. Therefore, understanding these habits in the initial stages should help to design the intervention more appropriately. As in this study, getting data from actual practices and interviewing with participants can help a researcher to determine the problem and initial situation. This will help the researcher develop effective solution proposals.

Finally, the product developed in this study promises to solve a determined problem. From the findings in this study and former literature, it was observed that most studies omit the inter-individual perspective of learning in science classroom, especially in gifted science classroom. In addition, studies that view meaning making semiotic resources developed by teacher as the part of pedagogic discourse of the teacher are scarce. The development of this product can be further extended to other grade levels in science classroom and other disciplinary fields. This study also foregrounds the relation between the pedagogical discourse and mediating tools that make meaning making possible. The training program developed in this study promises to foster science teachers' multimodal didactic text design competencies in gifted science classroom. Social semiotics and multimodality provide vast insights to describe, analyze, and evaluate the meaning making processes in science classroom. What is more, the collaboration of these two fields and design-based pedagogy proliferates new study focuses in gifted science classroom. In this respect, as the researcher of this study, I will focus on the multimodal design learning activities of gifted students in science classroom. In addition, the assessment and evaluation of multimodal learning products of students poses a challenge in current studies. In this respect, this study is seen as a starting point for investigating the multimodal meaning making and design processes in gifted science classroom. I will continue investigating mediating tools involving temporal semiotic resources and modes such as gestures used by teacher and the spatial positioning as a meaning making resource. The wider vision of this study, as one of my research aims in the near future, involves investigating assessment and evaluation of student generated learning products in the perspective of social semiotics and multimodality.

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A

AWARENESS INTEVIEW QUESTIONS

Araştırma Öncesi Mülakat Soruları

Soru 1.

6.sınıf öğrencilerinize direnç kavramını öğreteceksiniz. Öğrencilerinizin benzer önbilgiye sahip olduklarını varsayalım. Sınıf içinde veya çevrim içi ortamda anlatacağınız derste öğrencilerin Direnç kavramını anlamalarını ve anlamlandırmalarını neler etkileyebilir. Bu kavramı öğretirken neleri dikkate alırsınız?

Soru 2.

Bir bilimsel kavram öğrencilere sunuyor olsanız ve öğrencinin içeriği anlamlandırma süreci bir iletişim dahilinde gerçekleşiyor olsa, anlamayı desteklemek için iletişim sürecini hangi araçlar üzerinden ve nasıl gerçekleştirirsiniz? Bu iletişimi anlamlı kılan kaynaklar/öğretim materyalleri neler olabilir?

Soru 3.

Bir konuyu/kavramı (örneğin basınç kavramını) öğrencilerinize öğreteceksiniz ve bu öğretim sürecini gerçekleştirmek için gösterimler/yazılı metinler/sunumlar hazırlayacak olsanız, nasıl bir planlama yaparsınız?

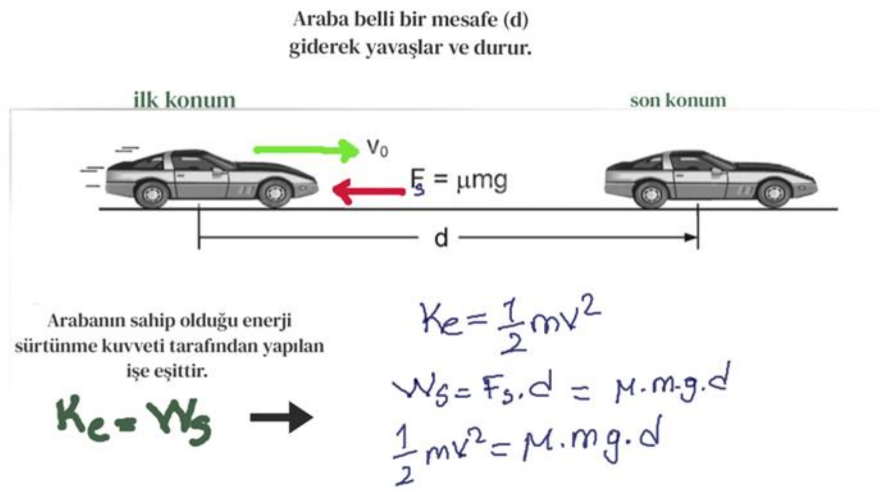
- Gösterim türlerini nasıl belirlersiniz?
- Gösterim türleri aslında bilimsel bilgilerin ifadeleridir. Bilimsel bilgiyi sunarken veya anlatırken kullanacağınız işaret/gösterimlerin öğrencilere aşinalık seviyesini nasıl belirlersiniz?
- Gösterimler öğrencilere nasıl zorluk sağlayabilir? Nasıl kolaylık sağlayabilir?

- Öğrencilerin bilişsel seviyeleri ve öğretmeninin kullanacağı gösterimler arasında bir ilişki kuruyor musunuz? Bu ilişki nasıldır sizce?

Soru 5.

Size göre metin ne anlama gelir? Bir örnek verebilir misiniz? Bilimsel metin ne anlama gelir?

Bu bir bilimsel metin. Bu metinden çıkardığınız anlamlar nelerdir veya bu metin size ne anlatıyor?

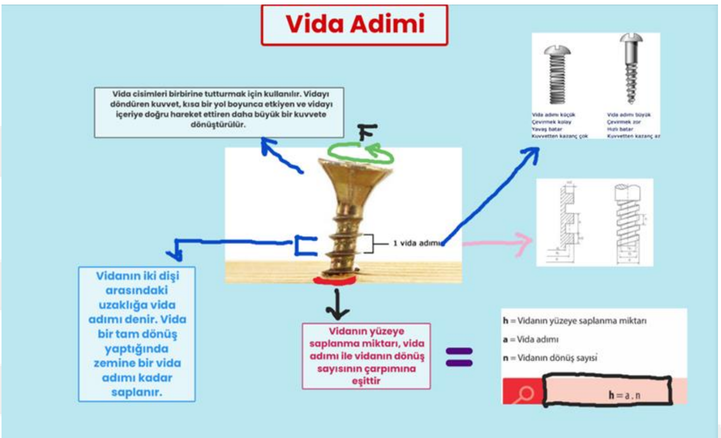


- En küçük anlam birimi nedir?
- Bu anlam birimleri hangi işaretlerle sunulmuş? Kendi aralarında sınıflandırabilir misiniz?
- Bu metinde birbirleri ile ilişkili olan varlıklar veya kavramlar nelerdir?
- Bu kavramlar arasına nasıl bir anlam ilişkisi vardır?
- Bu anlam ilişkileri hangi/nasıl gösterimlerle sunulmuş?
- Bu metinden yola çıkarak, tasarlayacağınız bir metin öğrencilerle ne tür öğrenme etkinliklerinin gerçekleştirilmesini sağlayabilir?

Soru 6.

Aşağıda vida adımı kavramını anlatan 2 görsel/metin tasarımı var. Bu kavramı öğreteceğiniz metin olarak hangi metni seçersiniz? Neden?


VIDA ADIMI
Vida cisimleri birbirine tutturmak için kullanılır. Vidayı döndüren kuvvet, kısa bir yol boyunca etkiyen ve vidayı içeriye doğru hareket ettiren daha büyük bir kuvvete dönüştürülür. Vidanın iki dişi arasındaki uzaklığa vida adımı denir. Vida bir tam dönüş yaptığında zemine bir vida adımı kadar saplanır. Vidanın yüzeye saplanma miktarı, vida adımı ile vidanın dönüş sayısının çarpımına eşittir
1 vida adımı
h = Vidanın yüzeye saplanma miktarı
a = Vida adımı
n = Vidanın dönüş sayısı
h = a . n
Vida adımı küçük
Çevirmek kolay
Yavaş batar
Kuvvetten kazanç çok
Vida adımı büyük
Çevirmek zor
Hızlı batar
Kuvvetten kazanç az
Adobe Spark


Vida Adimi
Vida cisimleri birbirine tutturmak için kullanılır. Vidayı döndüren kuvvet, kısa bir yol boyunca etkiyen ve vidayı içeriye doğru hareket ettiren daha büyük bir kuvvete dönüştürülür.
F
1 vida adımı
Vidanın iki dişi arasındaki uzaklığa vida adımı denir. Vida bir tam dönüş yaptığında zemine bir vida adımı kadar saplanır.
Vidanın yüzeye saplanma miktarı, vida adımı ile vidanın dönüş sayısının çarpımına eşittir
h = Vidanın yüzeye saplanma miktarı
a = Vida adımı
n = Vidanın dönüş sayısı
h = a . n

B

RECOGNIZE TEXT AND DISCUSSION QUESTIONS IN HLT1

Metin 1

Bir tepenin üzerinde aşağı doğru ilerleyen araba, h metre aşağıda ve d metre ileride bulunan trafik ışıklarında yavaşlayarak duruyor. Arabanın ilk durumda sahip olduğu toplam (mekanik) enerji aracın o an sahip olduğu kinetik ve potansiyel enerjinin toplamına eşit olduğunu biliyoruz. Enerji korunumu yasasına göre aracın ilk durumda sahip olduğu toplam (mekanik) enerji ve son durumdaki toplam enerjisine eşittir. Trafik ışığında duran aracın hızı olmadığından kinetik enerjisi, yüksekliği olmadığından potansiyel enerjisi sıfırdır. Peki ilk durumda aracın sahip olduğu toplam enerjiye ne olur? Araç durana kadar üzerine etki eden tek kuvvet sürtünme kuvvetidir. Sürtünme kuvveti aracın üzerinde iş yapar ve aracın durmasına sebep olur. Aracın son hali durgun hali olduğu için durgun halde sürtünme kuvveti de aracın üzerinde bir iş yapmaz. Aracın ilk durumda sahip olduğu toplam (mekanik) enerji ve sürtünme kuvvetinin aracın üzerinde yaptığı iş aracın durana kadar yapılan toplam iş yani enerji miktarını verir. Enerjinin korunumu yasasına göre, ilk durumda yapılan toplam iş son durumda yapılan toplam işe eşittir. Son durumda toplam iş yani enerji sıfır olduğu için aracın ilk durumdaki toplam enerjisi ile sürtünme kuvvetinin yaptığı toplam işin toplamı sıfırdır. İlk durumdaki toplam enerji sürtünme kuvvetinin yaptığı işin negatifi yani zıt yönlüsüdür. Kısacası aracıin ilk durumda sahip olduğu toplam enerji sürtünme kuvveti tarafından harcanır.

Tartışma Soruları

Bu metinde öğrencilere hatırlama ve anlama bilişsel seviyelerinde bir olgu anlatılmaktadır. Öğrencilerin metinde geçen kavramlara dair ön bilgiye sahip olduklarını varsayıyoruz.

1. Bu metne baktığınızda metin içerisinde olan kavramları ve varlıkları belirtebilir misiniz?
2. Metnin belirttiği kavramlar birbirleri ile nasıl ilişkilendirilmişlerdir?

Metin 2

Bir tepenin üzerinde ilerleyen araba, h m aşağıda ve d m ileride bulunan trafik ışıklarında yavaşlayarak duruyor. Aracın sahip olduğu enerji dönüşümleri nasıl olur?

Arabanın ilk durumda sahip olduğu toplam enerji: Ek + Ep

Ek = ½.m.v2

Ep =m.g.h

Enerji korunumu yasasına göre:

İlk durumdaki toplam enerji (Eilk) = Son durumdaki toplam enerji (Eson)

Ek (ilk) + Ep (ilk) = Eson

Son enerjiyi bulmak için, durgun aracın;

Vs=0 m/s ise Ek (son) = 0

hs=0 ise Ep (son) =0

Eson =0

Araç durana kadar sürtünme kuvveti aracın üzerinde iş yapar ve aracın durmasına sebep olur. Aracın son hali durgun hali olduğu için durgun halde sürtünme kuvveti de aracın üzerinde bir iş yapmaz.

Ek (ilk) + Ep (ilk) + Wsürtünme = Ek (son) + Ep (son) = 0 ise Ek (ilk) + Ep (ilk)= - Wsürtünme

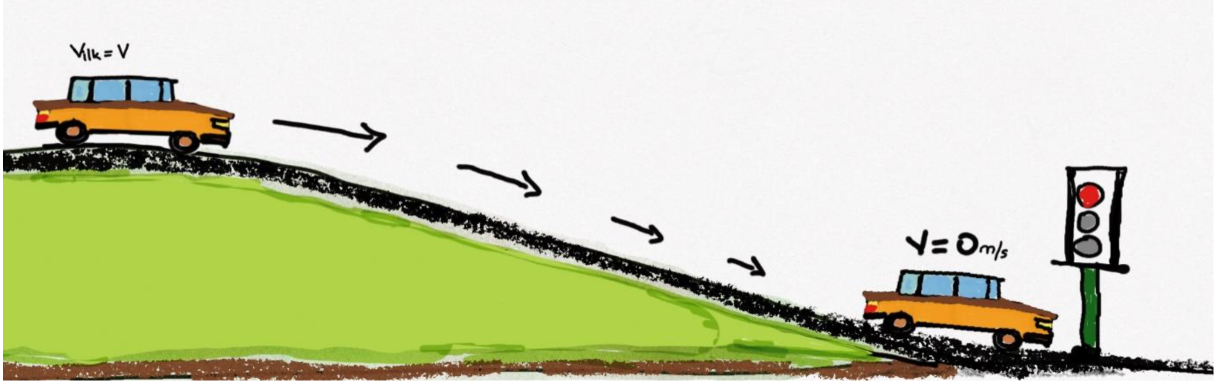
Yavaşlayarak duran aracın toplam enerjisi sürtünme kuvveti tarafından harcanır.

Tartışma Soruları

1. Bu metne baktığınızda önceki metinden farklı olarak süreç nasıl ifade edilmiş. Önceki metnin sahip olduğu metin yapısı ile bu metnin yapısını karşılaştırabilir misiniz?
2. Bu metinde yeni olarak ifade ettiğiniz temsiller veya modlar, metnin sahip olduğu kavramlar arasında nasıl bir ilişki kurmuş? Nasıl bir anlam ilişkisini temsil ederler?
3. Sizce bu tür bir anlam ilişkisini bu metin ifade eder?

Metin 3

Resimdeki araba, h metre aşağıda ve d metre ileride yavaşlayarak duruyor. Aracın ilk durum sahip olduğu toplam enerji dönüşümü nasıl olur?



Arabanın ilk durumda sahip olduğu toplam enerji: Ek + Ep

Ek = ½.m.v2 , Ep =m.g.h

Enerji korunumu yasasına göre:

Eİlk = ESon ve Ek (ilk) + Ep (ilk) = Eson

Son enerjiyi bulmak için, durgun aracın;

Vson =0 m/s ise Ek (son) = 0 ve hson =0 mt ise Ep (son) =0   Eson=0

Araç durana kadar sürtünme kuvveti aracın üzerinde iş yapar ve aracın durmasına sebep olur. Aracın son hali durgun hali olduğu için durgun halde sürtünme kuvveti aracın üzerinde bir iş yapmaz.

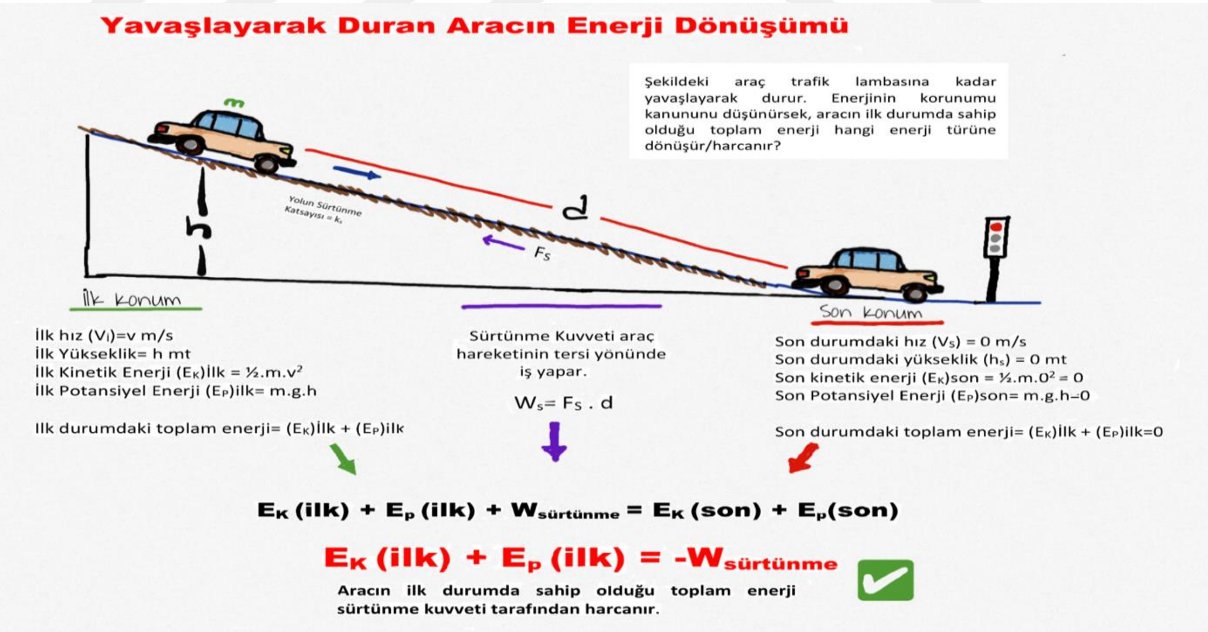
Ek (ilk) + Ep (ilk) + Wsürtünme = Ek (son) + Ep (son) = 0 ise   Ek (ilk) + Ep (ilk)= - Wsürtünme

Bir başka ifade ile, yavaşlayarak duran aracın toplam enerjisi sürtünme kuvveti tarafından harcanır.

Tartışma Soruları

1. **Bu** metin ve ilk 2 metni yapısal olarak karşılaştırabilir misiniz?
2. Resmin ifade ettiği kavramlar ve varlıklar nelerdir?
3. Bu metinde bir resim olduğunu görüyoruz. Bu resim bize neyi anlatmaktadır?
4. Birinci veya ikinci metinle karşılaştırırsak, bu resmin ifade ettiği anlamları bu iki metindeki yazı modları ifade edebiliyor mu? Ediyorsa veya edemiyorsa neden?

Metin 4



Tartışma Soruları

1. Bu metinde fark ettiğiniz kavramlar ve varlıklar nelerdir?
2. Bu kavramlar ve varlıklar hangi işaret-mod-gösterimlerle sunulmuş?

3. Bu kavramlar hangi modlar- gösterimler ile birbirleri ile ilişkilendirilmişler?
4. Sizce bu metinde kullanılan kaynaklar içeriği diğer metinler göre ne kadar anlamlı bir yolla ifade sunabiliyor?
5. Bu metin ile diğer metinleri karşılaştırırsanız yapısal olarak ne fark(lar) vardır?

Özet Tartışma Soruları

1. Mekanik enerjinin sürtünme enerjisine dönüşümü olgusunu öğrencilerinize sunacak olsaydınız, bu 4 metinden hangisini tercih ederdiniz? Neden?
2. Öğrencilerinize bu konu ile ilgili bir tasarım yaptıracaksınız. Öğrencilerinizin yaratıcı tasarımlar yapabilmesini bekliyorsunuz. Daha öncesinde içeriği sunmanız gerekiyor. Öğrencilerin yaratıcılıklarını artıracak kaynaklar sunması bakımında bu dört sunumdan hangisini tercih ederdiniz? Neden?

C

RECOGNIZE TEXTS AND DISCUSSION QUESTIONS OF HLT2

Metin 1

Tartışma Soruları

1. Metni incelediğinizde, metni anlamlandırmak için gerekli olan ön bilgiler nelerdir?
2. Metnin anlatmak istediği içeriği/konuyu genelden özele sıralayabilir misiniz?
3. Bu metinde kullanılan modlar hangileridir?
4. Bu metinde öne çıkarılan, en çok fark ettiğiniz özellik/konu/husus nedir?
5. Vurgu yapılan husus/veya özellik nasıl bir strateji ile fark edilebilir hale getirilmiştir?
6. Öne çıkarılan hususun hangi durumları veya örnekleri verilmiş?

Metin 2

Tartışma soruları

1. Metni incelediğinizde, metni anlamlandırmak için gerekli olan ön bilgiler nelerdir?
2. Metnin anlatmak istediği içeriği/konuyu genelden özele sıralayabilir misiniz?
3. Bu metinde kullanılan modlar hangileridir?
4. Bu metinde öne çıkarılan, en çok fark ettiğiniz özellik/konu/husus nedir?
5. Vurgu yapılan husus/veya özellik nasıl bir strateji ile fark edilebilir hale getirilmiştir.
6. Öne çıkarılan hususun hangi durumları veya örnekleri verilmiş?

Karşılaştırma Soruları ve Tartışma

Tartışma Soruları

1. Bu metinleri metin tasarlama stratejisi açısından karşılaştırdığınızda aralarında hangi farklar vardır?

2. Bu farklar hangi amaçlara hizmet eder?

3. Kovalent bağın özelliklerini sunmak istediğinizde hangi metni kullanırsınız? Neden?

4. Kullanacağınız bu metin bu anlamı oluşturmak için hangi özelliklere sahip?

D

DESIGN INTERVIEW QUESTIONS

Multimodal Metin Tasarımı Soruları

1. Bu metni tasarlarken genel olarak stratejiniz neydi?
2. Bu metni tasarlarken sadece yazı modunda veriler metinde hangi varlık ve kavramları belirlediniz?
3. Bu varlık ve kavramları göstermek/temsil etmek için hangi modları kullandınız?
4. Neden bu modları kullandınız? (Hem yazı hem de resim ile var).
5. Bu modlar içerisinde kullandığınız semiyotik kaynaklar (renk veya kalınlık-incelik gibi) metinde nasıl bir etki yarattı sizce?
6. Bu varlıklar ve kavramlar arasında hangi anlam ilişkilerini belirlediniz?
7. Bu anlam ilişkilerini göstermek/temsil etmek için hangi modları seçtiniz?
8. Neden bu modları modları seçtiniz? Bu modların içeriği anlamlandırmada rolleri nedir?

Multimodal Metin Varyasyon Soruları

1. Bu metni tasarlamaya karar verdiğinizde ilk olarak ne yaptınız veya neyi düşündünüz?
2. Metni neden böyle bir yapıda tasarladınız?
3. Bu metinde sizce en önemli husus veya bilgi nedir?
4. En önemli veya kritik husus sizin için ne anlama gelir?
5. Bu hususları göstermek için neden bu modları seçtiniz?
6. Bu metin içerisinde kritik hususları öne çıkarma işlemine nasıl karar verdiniz?
7. Çevresel önemdeki bilgiler ve gösterimler hangileridir?

8. Benimsediğiniz varyasyon stratejisi neyi amaçlar?

9. Bu metinde kullanılan varyasyon stratejisinin nihai olarak neyi amaçlar?

10. Semiyotik ekonomi kavramı size neyi çağrıştırır?

11. Bu metinde semiyotik ekonomi ilkesi adına izlediğiniz bir strateji oldu mu?

E

IMPLEMENTATION EVALUATION INTERVIEW QUESTIONS

1. Bu öğretim süreci, önce farkındalık, sonra tanıma, sonra video yoluyla öğretme ve tasarım ve geridönüt süreci sizce:
    a. Multimodal metinler tasarlamada etkilimidir sizce? Neden?
    b. Gelecekte yapılacak dersler için sürekliliğe sahip midir? Neden? Neler tekrardan düzenlenmelidir?
2. Yapılan aktiviteler multimodalite kavramını anlamada size nasıl yardımcı oluyor ve multimodal metin tasarlamanızı etkili bir şekilde destekliyor? Ne yapmalıyız? Bunu besleyen veya engelleyen koşullar nelerdir? Siz yapsanız neler yapardınız.
3. Hangi aktiviteler multimodal metin tasarlamada size daha yardımcı oldu? Nasıl? Siz yapsanız neler yapardınız.
4. Süreç içerisinde yaşadığınız zorluklar nelerdir? Bu zorlukları aşmak için siz ders sürecini nasıl tasarlardınız?
5. Tasarladığınız metinlerdeki yazı içinde ve yazı-görseller arasında hangi tür anlam ilişkileri tasarladınız? Ve bunları nasıl gerçekleştirdiniz?
6. Uygulama sürecinde; kullanılan araçlar ve zaman kullanımı hakkında ne düşünüyorsunuz?
7. Araştırmacının rolleri ve sizlerin tasarım süreçlerindeki rolleri hakkında ne düşünüyorsunuz?
8. Tasarlanan aktivitelerle sizce bundan sonra bir sunum veya bilimsel metin seçerken veya tasarlarken nelere dikkat edersiniz? Bu ders süreci bu amaçları karşılamak için daha etkili hale nasıl getirilebilir?

9. Aktivite tasarlarken yapmak istediğinizle yaptığınız arasında ne gibi farklılıklar var? Sizce neden gerçekleşmiyor? Halihazırda bulunan ve benimsenmiş program ve materyaller bunu etkiliyor mu? Nasıl?

F

FINAL DESIGN INTERVIEW QUESTIONS

Sorular

1. Öğrencilerinize belli bir konuyu anlatmadan önce derste kullanacağınız bir veya daha fazla hareketsiz öğrenme kaynağını neleri dikkate alarak tasarlarsınız veya seçersiniz?
2. Kullanacağınız bir metin öğrenme süreçlerinde ne gibi etkiler yaratabilir? Neleri etkileyebilir?
3. Çokmodluluk kavramı size ne ifade eder ve bilimsel anlamı çokmodlu olarak nasıl tanımlarsınız?
4. Çokmodlu metinler anlamlandırmayı ve öğrenmeyi nasıl kolaylaştırabilir?
5. Öğrencilere sunacağınız metinler öğrencilerin daha sonra oluşturacakları öğrenme ürünlerini nasıl etkileyebilir?

(Feedback öncesi ve sonrası metinleri göstererek), bu değişimi yapmanızın arkasında yatan sebep nedir?

- Bu metni tasarlarken hangi stratejileri kullandınız?
- Oluşturmak istediğiniz anlam türleri ve anlam ilişkisi türleri nelerdir?
- Neden bu figürü ortaya koydunuz?
- Neden başlığı buraya koydunuz?
- Yazı ile resim istediğiniz anlamı nasıl oluşturdu?
- Burada bu semiyotik kaynağı veya modu kullanmak ne işinize yaradı?
- Burada farklı örnek veya durumlar var. Bunları göstermek anlamlandırma üzerine ne gibi bir etki bırakabilir?
- Bu yazı tiplerini neden farklı yazdınız?

PUBLICATIONS FROM THE THESIS

Papers

1. Ayık, Z., & Coştu, B. A Study on Effects of Multimodal Science Text Design on Meaning-Making of Science Content: Science Teachers' Perspectives. *Mimbar Sekolah Dasar*, 8(1), 1-20.

Conference Papers

1. Ayık, Z., & Coştu, B. (2021). Özel Yetenekli Öğrencilerin Fen Öğretmenlerinin Multimodal Metin Tasarım Becerilerinin Geliştirilmesi: Bir Eğitim Tasarım Araştırması. 14. Ulusal Fen Bilimleri ve Matematik Eğitimi Kongresi, 285, Burdur, Türkiye.